STUDIES ON THE ANATOMY OF SOUTH INDIAN TIMBERS.

BY

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C O N T E N T S.

INTRODUCTION

The first account of Indian Timbers was published in 1831 by Dr. Aitken. His studies were confined to the Timbers of Assam. In 1881 J.S. Gamble published The Manual of Indian Timbers which comprised a brief survey of the various timbers of the different parts of India. A more complete and much more extensive edition of his work was published in 1920. Mr. R.S. Pearson and Dr. H.P. Brown, published a detailed account of the "Commercial Timbers of India" in 1932. During the past few years Dr. K.A. Chowdhury of Dehra Dun has made very extensive studies of numerous timbers, chiefly of N. India.

The materials examined here are some of the lesser known timbers, particularly of Malabar (Travancore - Cochin State). They are mostly confined to the rain forest region and the adjoining plains. These trees have not been studied in detail before. As yet no exhaustive or complete account of the timbers of S. India has been made, though some of the most important and well known commercial timbers have been described by the persons mentioned above. The present work has been carried out with a view to describe the structure, to identify certain timbers, and to make an exhaustive and analytical study of the behaviour of the various wood elements of the dicotyledonous trees of the rain-forest area where growth is almost continuous throughout the year.

The first part of the work comprises a detailed account of the anatomical structure of the various trees under investigation with a brief account of their external morphology, habit and habitat.

The second part consists of a detailed account of the structural variations brought about in the various wood elements in the growth of the tree. No such work on Indian Timbers has been done before.

PART I

Material and Method.

The materials were collected from different parts of the Travancore area when the trees were in flower. Five trees of each species of over 15 years of growth have been selected. They were cut down and discs of three inches in thickness were taken (a) at the bottom, one foot above the soil surface and (b) at the top of the trunk one foot below the first branching and correctly labelled. They were dried and painted with mercuric chloride on the cut surface to prevent fungal attack.

Herbarium material from each of the selected tree was prepared for identification and morphological studies.

The distribution of the trees and their ecology were also noted during the collection of the materials.

The discs thus prepared were used for anatomical studies in the Laboratory.

Blocks of the size 1.5cm x 1.0cm x 1.0cm were cut from the various discs. They were boiled separately until they sank. Thereafter the blocks were preserved in a mixture of equal quantity of 50% alcohol and 50% glycerine for 7 days before cutting.

Transverse, longitudinal radial and tangential sections were taken at suitable thickness (10 - 30μ). They were stained in safranin and permanently mounted.

A portion of each of these blocks was macerated according to Schultze's method. Small splinters were taken from the block and they were left in dilute nitric acid with a pinch of potassium chlorate for a period of 24 hours. Then they were washed in water and shaken well in a test-tube containing water. The various elements thus became separated.

The terms used in the anatomical descriptions are those recommended by the Committee on Nomenclature of the International Association of Wood Anatomists (2).

The diameter of the vessels are described according to the size classes laid down by Chalk (5)

Extremely small	up to 25μ
Very small	25 - 50 μ
Moderately small	50 - 100μ
Medium sized	100 - 200μ
Moderately large	200 - 300μ
Very large	300 - 400μ
Extremely large	over 400μ

The number of vessels per sq:millimeter were noted and described according to the scheme laid down by Chattaway (8)

Up to 2	Very few
2 - 5	Few
5 - 10........	Moderately few
10 - 20........	Moderately numerous
20 - 40........	Numerous
Over 40........	Very numerous

For length of vessel members (in μ) the classification proposed by the Committee on the Standardization of Terms of Cell Size of the International Association of Wood Anatomists (3) is followed.

Extremely short	less than 175 μ
Very short	175 - 250 μ
Moderately short	250 - 350 μ
Medium sized	350 - 800 μ
Moderately long	800 - 1100 μ
Very long	1100 - 1900 μ
Extremely long	Over 1900 μ

The vessel members were measured on macerated material and their "total length" is recorded as proposed by Chalk and Chattaway (7).

The following standard terms of size were used for describing wood fibres Comm. Inter. Wood Anatomists (3).

Extremely short	500 μ
Very short	500 - 700 μ
Moderately short	700 - 900 μ
Medium sized	900 - 1600 μ
Moderately long	1600 - 2200 μ
Very long	2200 - 3000 μ
Extremely long	over 3000 μ

For describing the rays the following standards were used. Comm. Inter. Wood Anatomists (4).

Ray Width

Extremely fine	up to 15 μ
Very fine	15 - 25 μ
Moderately fine	25 - 50 μ
Medium sized	50 - 100 μ
Moderately broad	100 - 200 μ
Very broad	200 - 400 μ
Extremely broad	over 400 μ

Spacing of the Rays.

Widely spaced	5 or less rays per mm
Normally spaced	6 - 9 rays per mm
Fairly close	10 - 13 " " "
Close	14 - 20 " " "
Extremely close	21 or more rays per mm

Fifty to a hundred counts were made and the mean calculated so that the varying character of each element from different aspects could be described.

The terms of description of xylem parenchyma follow the listing of Metcalfe and Chalk (12).

<u>Apotracheal parenchyma</u>

Terminal

Diffuse) scattered
)
) diffuse-in-aggregate

Metatracheal or banded

<u>Paratracheal parenchyma</u>

Scanty

Abaxial

Vasicentric

Aliform

Aliform - confluent

Confluent

Ray types based on Kribs (10) which have been followed by Metcalfe and Chalk are used in the description. These types are:

Heterogeneous 1, 11A, 11B, 111

Homogeneous 1, 11, 111

The species studied were:

(1) <u>Pajanelia rheedii</u> Wight .... Bignoniaceae

(2) <u>Erythrina stricta</u> Roxb .... Papilonaceae

(3) <u>Macaranga peltata</u> Muell Arg .... Euphorbiaceae

(4) <u>Tabernaemontana dichotoma</u> Roxb.. Apocynaceae

(5) <u>Anacardium occidentale</u> Linn .... Anacardiaceae

P A J A N E L I A DC.

(Plates 1 - 5)

The genus Pajanelia (family Bignoniaceae) is a small one in which only two species have been described. Pajanelia multijuga DC., distributed over a large area, Assam, Lower Burma and the Andamans, is a large tree reported to flower from November to February. Pajanelia rheedii Wight, found in Malabar, is a small tree which flowers in July and August. It is the latter species which is investigated here.

Pajanelia rheedii Wight

The tree is known as "Payani" in the vernacular. It is a small weak tree 30-60 ft. in height with grey brown bark.

Leaves 2-4ft. long, common petiole, angled, imparipinnate 5-12 pairs of opposite leaves on each rachis. Each leaflet is 3-8 in. long, $1\frac{3}{4}$-$3\frac{1}{4}$ in. broad, very oblique at the base, with a long acuminate apex and entire margin. The primary veins, the reticulated veinlets and venules are very prominent beneath.

Flowers large, on erect panicles, which are 14-20 in. long. The flower is $3\frac{1}{2}$-4 in. long.

Calyx coriaceous, campanulate, 5-lobed.

Corolla campanulate, sub-bilabiate. The corolla tube is contracted below the middle, glabrous on the outside. It is dull purple in colour.

Lobes 5, dilated and crisp on the outer margin, provided with a line of dense hairy outgrowths on the inner edge.

Stamens 4 fertile, a 5th scarcely sterile, shorter than the others.

Ovary provided with a 2-lobed, clavate stigma.

Capsule flat with a broad wing, 12-20 in. long, $2\frac{1}{2}$-$3\frac{1}{2}$ in. broad, glabrous. The wing on each margin split so that the capsule appears 4-winged.

Seeds compressed and winged, mostly rounded, $\frac{1}{2}$ in. diameter.

Distribution.

The tree is distributed all over Malabar, especially in Travancore, in the plains and also up to a height of 2,000 ft. Often it is cultivated to support *Piper nigrum.*

The Timber

Sapwood yellowish-white in colour when freshly cut but turning slightly brown when dry. The heartwood can be distinguished easily with its dark brown colour especially when fresh. Generally the heartwood does not form till the trees are beyond 20 years of age. The wood is of even texture with moderately close and straight grain.

The growth rings are not distinct to the naked eye. Even with a hand lens they are scarcely discernible.

Pores few, visible to the naked eye.

The soft tissue moderately abundant surrounding the pores, visible under the lens.

Rays fine, visible to the naked eye.

Microscopic features.

Growth rings inconspicuous, marked by an increase in thickness of the fibre walls and a slight decrease in the size of the vessels towards the end of the ring. The cells at the outer margin of the growth ring are slightly flattened radially.

Vessels medium sized, moderately large, and very large 150-320μ in diameter. They are larger in size through the central portion of the ring and decreasing in size in the late wood. They are few, 3-4 per sq.mm., mostly oval, generally occurring singly, sometimes in groups of 2 or occasionally 3. Throughout the ring the vessels are fairly evenly distributed. The vessel member is moderately short to medium-sized 280-490μ long, medium thin-walled, truncate or abruptly or attenuately tailed.

Perforations simple, oblique. Multiple perforations also occur rarely. Tyloses, which are globose, are present occasionally.

Intervascular pitting alternate, numerous. The diameter of the pit is 5-7μ. The pits are orbicular or oval, occasionally polygonal in shape. The pit aperture is small and round.

Pits leading to contiguous ray and parenchyma cells are numerous, larger than the intervascular pits. They are very variable in shape, orbicular or elliptical with narrow border and wide orifice reaching nearly to the margin of the pit court. The diameter of the pit is 8-25μ.

<u>Parenchyma</u> is paratracheal, vasicentric, sometimes aliform. Cells fairly constant in size and shape. Those cells which are in touch with the vessels are laterally compressed. There are no crystals. There are no pits on the walls in contact with the fibres.

<u>Fibres</u> are non-septate, libriform, angled in the transverse section and aligned in regular radial rows. They are very short, moderately short and medium-sized varying from 660-1200μ in length with a diameter of 20-45μ. The walls are 3-6μ in thickness. Pits are confined to the radial walls, simple or with narrow border and with slit-like nearly vertical orifices.

<u>Rays</u> are widely or normally spaced, 4-6 per mm. 1-3 seriate; uniseriate rays infrequent. They are fine to moderately fine 22-44μ in width formed by 1-3 cells. The height of the ray is 244-944μ formed by 10-27 cells. The rays are homogeneous, type IIA Kribs, consisting of procumbent cells with very thin walls. Crystals are not present. The cells in contact with the vessels are laterally compressed while those touching the wood parenchyma are dilated.

Discussion.

The characters observed in *Pajanelia rheedii* have been compared with the general anatomical characters of the wood described by Metcalfe and Chalk (12), and by Pearson and Brown (13) for the family Bignoniaceae. Multiperforate vessels observed by Chalk (6) and Pearson and Brown (13) in certain species of the family occur very rarely in *Pajanelia rheedii.* Some species in this family have "lapachol" in an impure state which turns pink Record (14) or wine red Pearson and Brown (13) on treatment with alkalies. *Pajanelia rheedii* does not show such a reaction on treatment with dilute solution of sodium carbonate.

The anatomical characters of the wood of *P. multijuga* were observed from a slide at the Imperial Forestry Institute, Oxford, and compared with those of *P. rheedii.* It was noted that in the former the vessels were moderately few or moderately numerous, 5-15 per sq.mm. and in the latter they are few, 3-4 per mm. Multiperforate vessels were more frequent in P. multijuga.

PAJANELIA RHEEDII

PLATE I.

a - c. Vessel members x 150

d. R.L.S x 150 showing the intervascular pits and pits to parenchyma

e. Intervascular pits x 950

f. Pits to parenchyma x 950

PLATE 2.

g - j. Fibres x 150

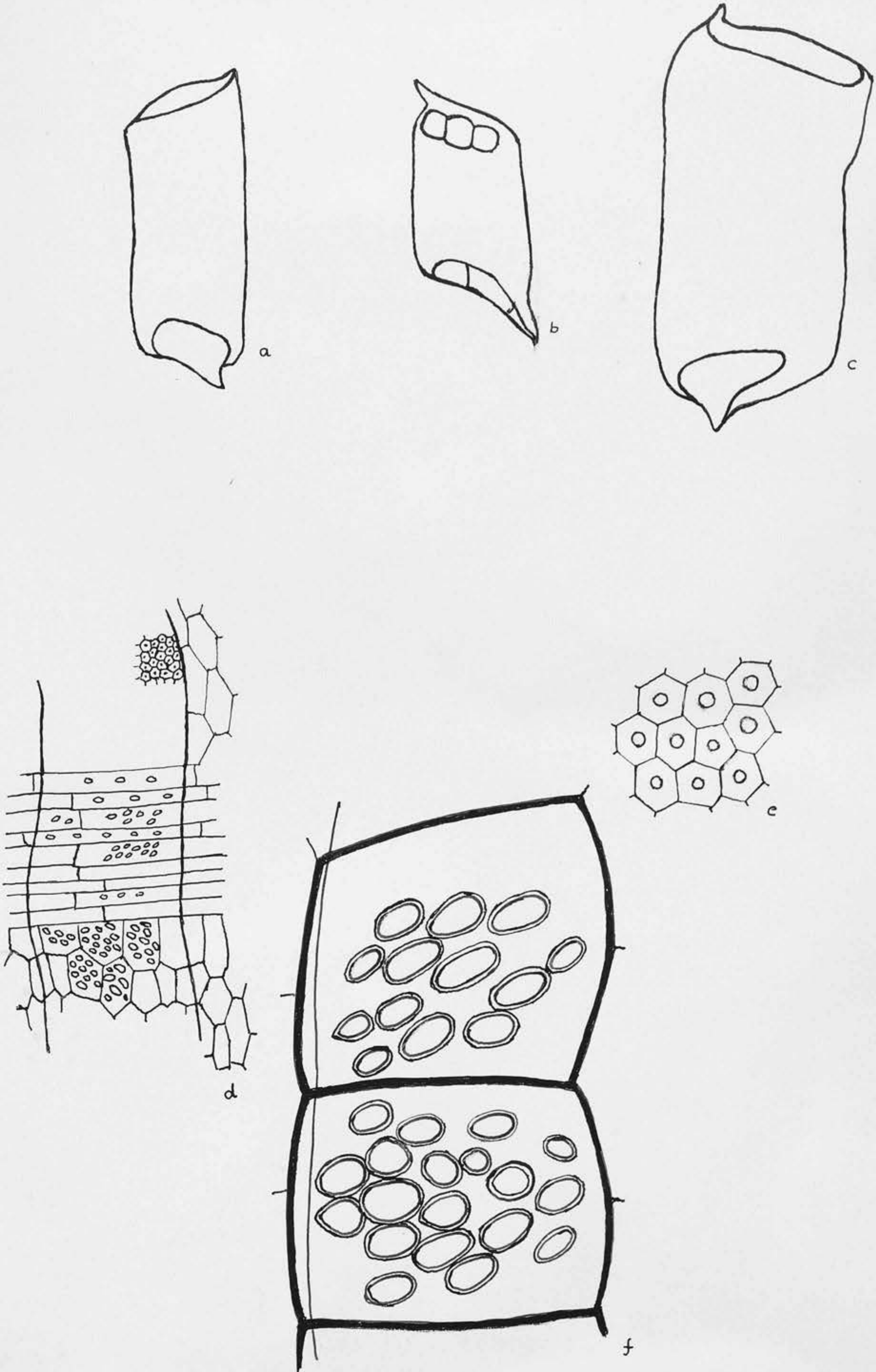
k - m. Rays (T.L.S) x 150

PLATE 3. T.S. x 20

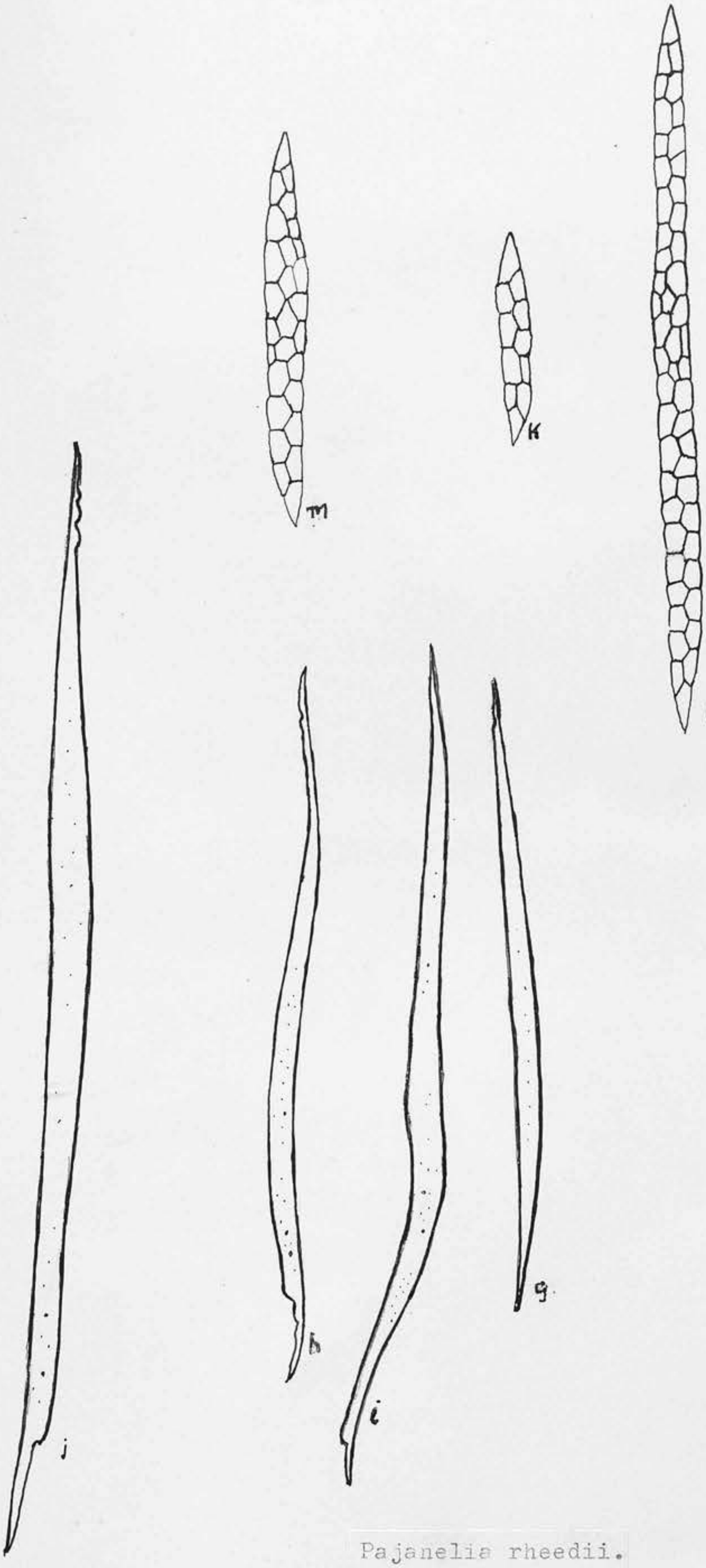
PLATE 4. T.S. x 50

PLATE 5. T.L.S. x 100

PLATE I



Pajanelia rheedii.



Pajanelia rheedii.

PLATE 3

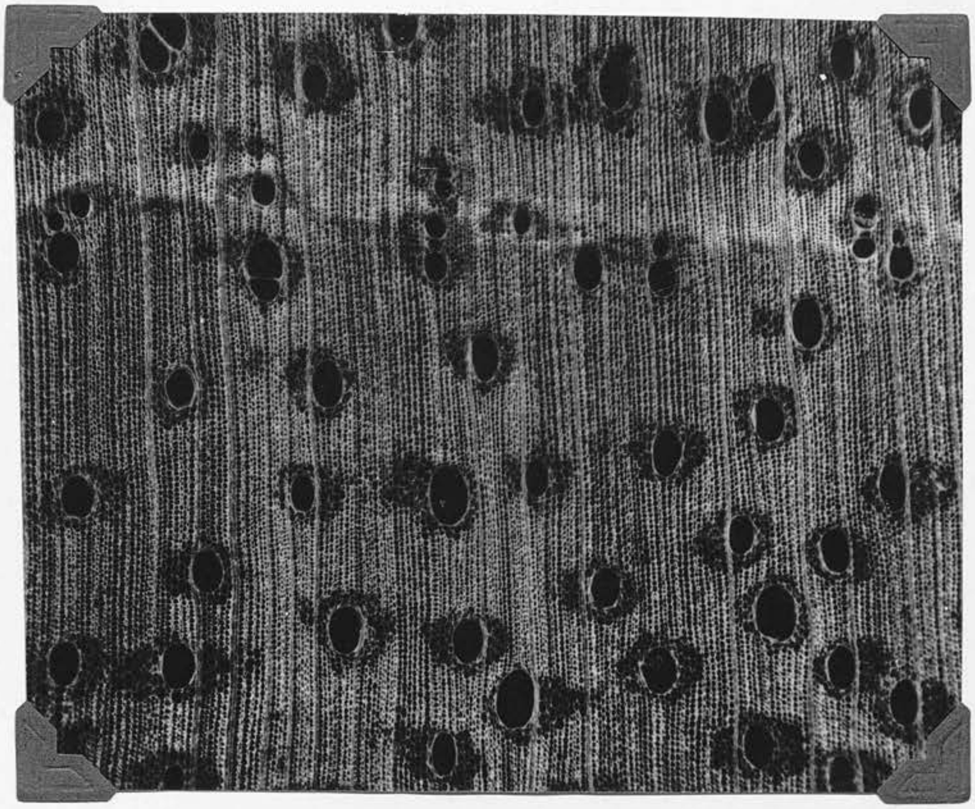
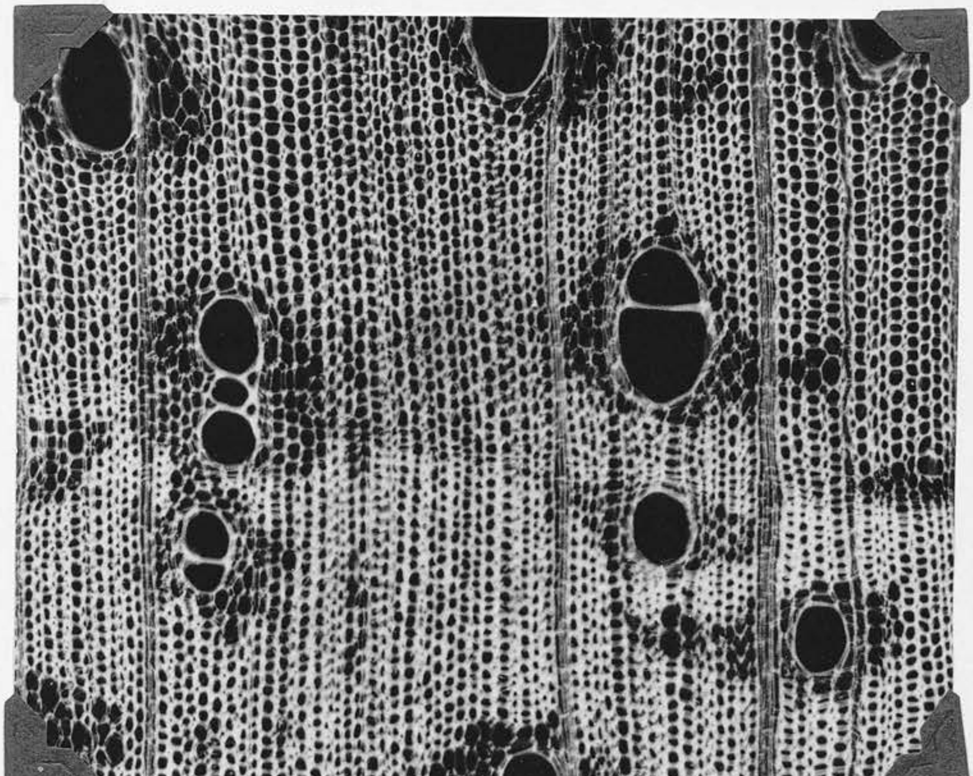
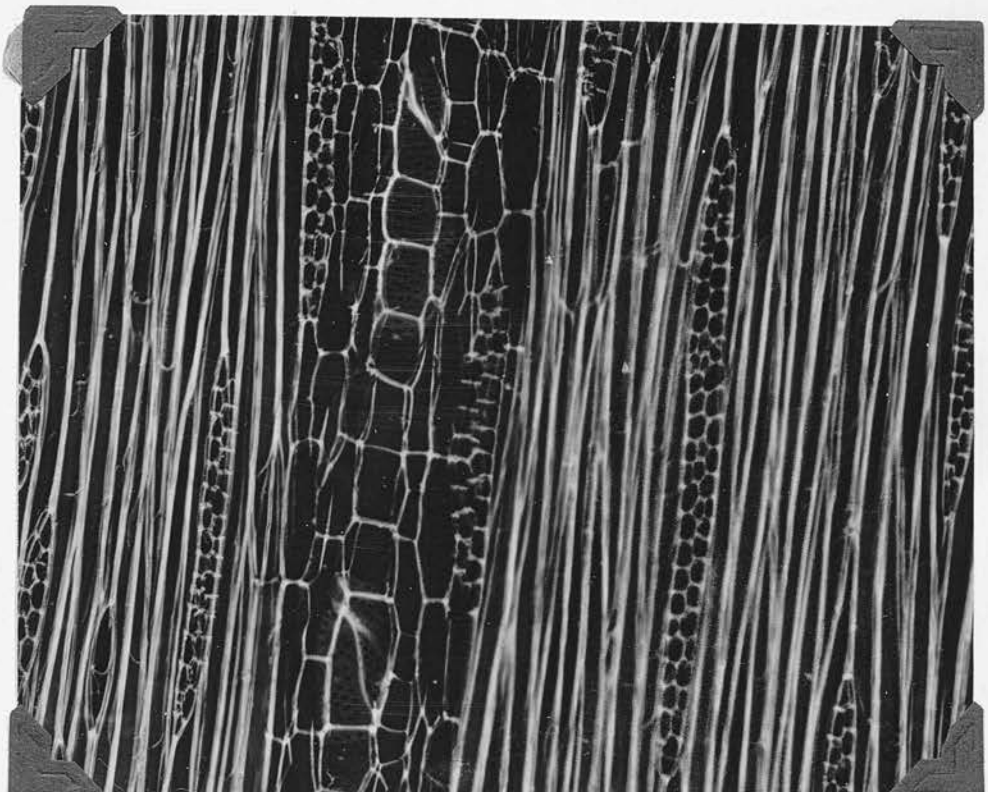


PLATE 4



Pajanelia rheedii.

PLATE 5



Pajanelia rheedii.

<u>ERYTHRINA</u> Linn.

(Plates 6 - 11)

<u>Erythrina</u> is a large genus (family Papilionaceae) consisting of several species about seven of which occur in India. The species under investigation here is <u>Erythrina stricta</u> Roxb. <u>Erythrina stricta</u> Roxb. is a large tree of very rapid growth known as 'Murukku' in Malayalam. It has a corky bark armed with stout, conical prickles which fall off when a few years old.

<u>Leaves</u> pinnately three-foliate with small stipules. Stipels are present. The leaflets membranous, deltoid-ovate, abruptly acuminate and with entire margin. Generally the terminal leaflet 4-5 ins. long.

<u>Flowers</u> in dense racemes. They are large and red in colour.

<u>Calyx</u> deeply lobed

<u>Corolla</u> shows the standard petal, wing petals and keel petals. The standard is 1 - 1.25 in. long, wings minute, 0.2 in. long, and keel petals 0.75 in. long.

<u>Stamens</u> 10.

<u>Ovary</u> stipitate, many ovuled, style curved, stigma capitate.

<u>Fruit</u> a pod, 6-8 ins. long, 2-5 seeded.

Distribution.

Erythrina stricta is distributed mainly in the west coast of India especially in Travancore - Cochin State up to a height of 3000 ft. It grows wild in the forest and it is cultivated in the plains and hillsides as a support for growing Piper nigrum.

The Timber

The wood is pale yellow when freshly cut and turning to pale yellowish-grey when dry. It is light, tough and fibrous, straight grained and coarse textured. Heartwood is not differentiated by colour.

Growth rings are not visible

Pores are few, clearly visible to the naked eye

Soft tissue which is abundant is seen in bands by the naked eye

Rays visible to the naked eye

Ripple marks noted on the tangential section of the wood.

Microscopic features.

Growth rings scarcely distinct even under the microscope.

Vessels vary considerably in size, medium-sized, moderately large, very large and extremely large from 100-420μ in diameter. They are very few, 1-2 per sq:mm., mostly round in shape occurring solitary or occasionally in groups of 2, 3 or 4. They are inserted in broad concentric bands of parenchyma.

Vessel members are cylindrical, very short, thin-walled, 200-250μ in length, more often broader than long.

Perforations simple, generally horizontal.

Intervascular pits numerous, angular with wide border, and lenticular orifice.

Pits to ray and parenchyma are numerous, elliptical with narrow border and elongated lens-shaped orifice. Pits are as large as those of the vessels.

Parenchyma is very abundant, paratracheal, confluent occurs in more or less regular bands of 5 - 12 cells wide. In transverse sections the cells are seen in radial rows. In tangential sections they are storied with fusiform strands of 2 cells. Crystals occur in chambers which are 4 - 12 in number, arranged in series.

Fibres are non-libriform, angled in the transverse section. They are arranged in bands which alternate with the bands of parenchyma. The bands of fibres are narrower than those of parenchyma. The diameter of the fibres vary from 10-18μ and the thickness of the fibre wall from 9 - 12μ. The fibres are medium sized, moderately long and very long. The length of the fibre varies from 1200 - 2500μ.

Rays are widely spread, 2 - 3 per mm. They are mostly multiseriate but uniseriate rays also occur. The multiseriate rays 4-15 cells wide and 6-57 cells high. They are moderately broad varying from 100-200μ and the height from 400-1670μ. The rays are heterogeneous type II A Kribs. Marginal cells are larger than the others. Sheath cells are present.

Discussion

According to J.S. Gamble (9) three other species of Erythrina also occur in S. India, besides Erythrina stricta Roxb. They are E. indica Lam., E. mysorensis Gamble and E. suberosa Roxb.

E. suberosa is described by Pearson and Brown (13). It is confined mostly to the regions of N. India but it occurs in S. India in the dry forests of N. Circars and Deccan up to 3000 ft., Gamble (9).

The detailed anatomical account of the wood of E. suberosa given by Pearson and Brown is compared to that of E. stricta. The vessels in the former vary from "extremely large to small or very small without transitional sizes". In the latter the vessels vary from medium sized to extremely large showing transitional sizes.

The fibres in *E. suberosa* are generally shorter than those of *E. stricta*. In the first the fibres vary from 445 - 2230μ whereas in the second the variation is from 1200 - 2500μ. The thickness of the fibre wall in *E. suberosa* is only 3-4 and in *E. stricta* 9-12

E. stricta	E. suberosa
Vessels medium to extremely large. 100-420μ in diameter	*Vessels* very small to large. Up to 445μ in diameter
Parenchyma Paratracheal, more or less regular bands	*Parenchyma* Paratracheal zonate or metatracheal
Fibres 1200-2500μ in length	*Fibres* 445-2230μ in length
Fibre wall 9-12μ in thickness	*Fibre wall* 3-4μ in thickness

Thus the two species can be identified.

The anatomy of the wood of the other two species *E. mysorensis* Gamble and *E. indica* Lam. has not been studied in detail.

ERYTHRINA STRICTA

PLATE 6.

a - c.	Vessel members x 150.
d.	R.L.S. x 150 showing the intervascular pits and pits to parenchyma.
e.	Intervascular pits x 950
f.	Pits to parenchyma x 950

PLATE 7.

g - h.	Rays (T.L.S) x 150
i - j.	Fibres x 150
k.	Chambered crystals x 150

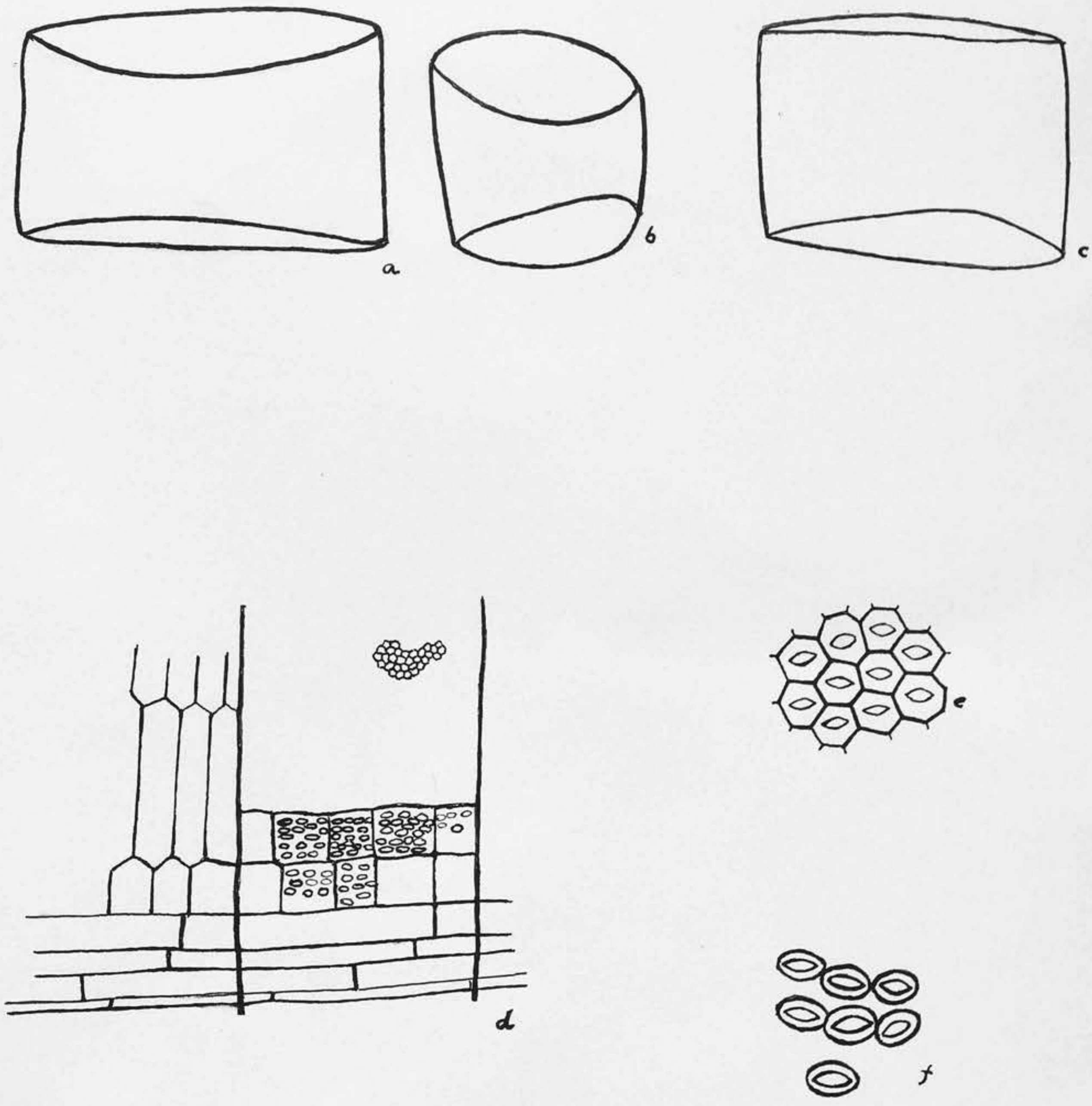
PLATE 8. T.S. x 20

PLATE 9. T.S. x 50

PLATE 10. T.L.S. x 100

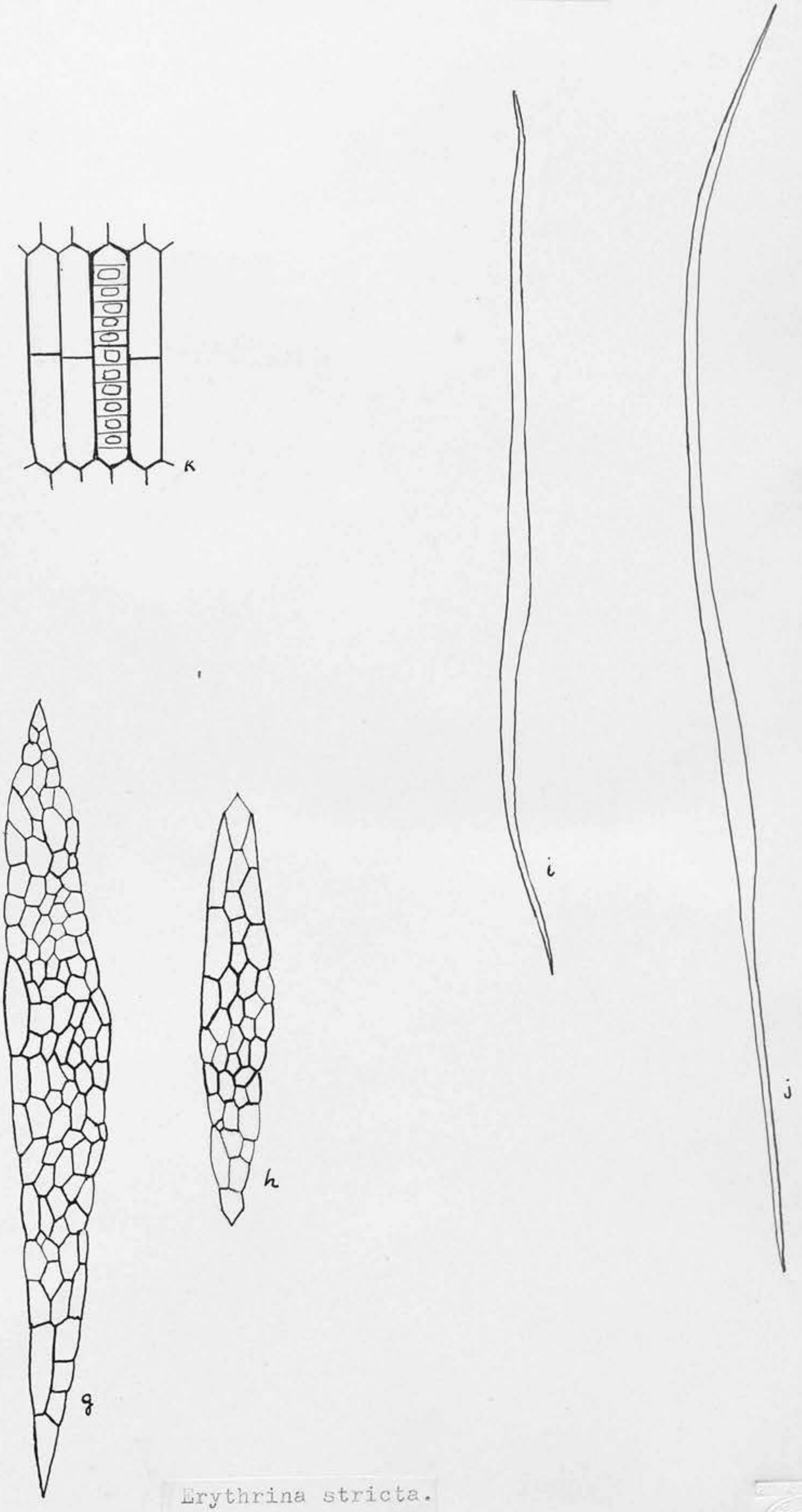
PLATE 11. Chambered crystals x 350

PLATE 6



Erythrina stricta.

PLATE 7



Erythrina stricta.

PLATE 8

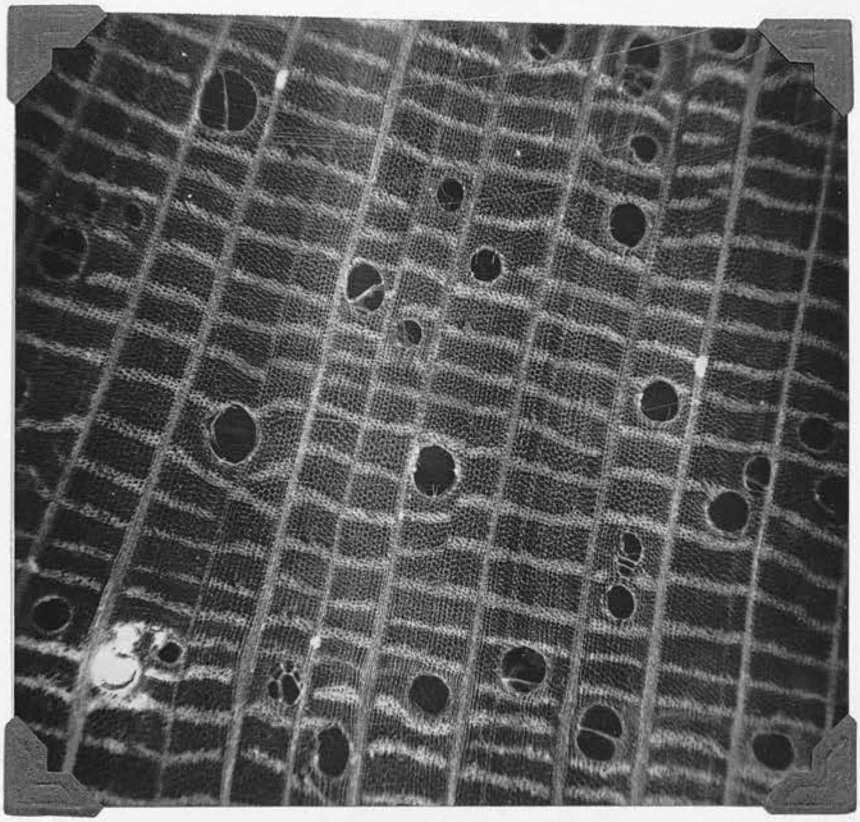
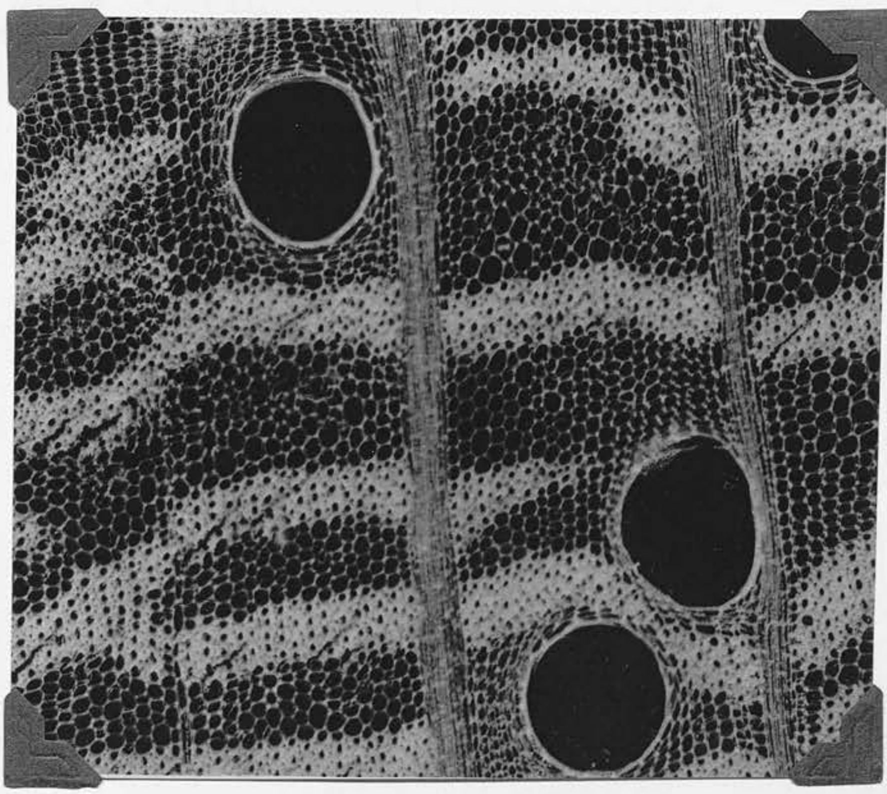


PLATE 9



Erythrina stricta.

PLATE IO

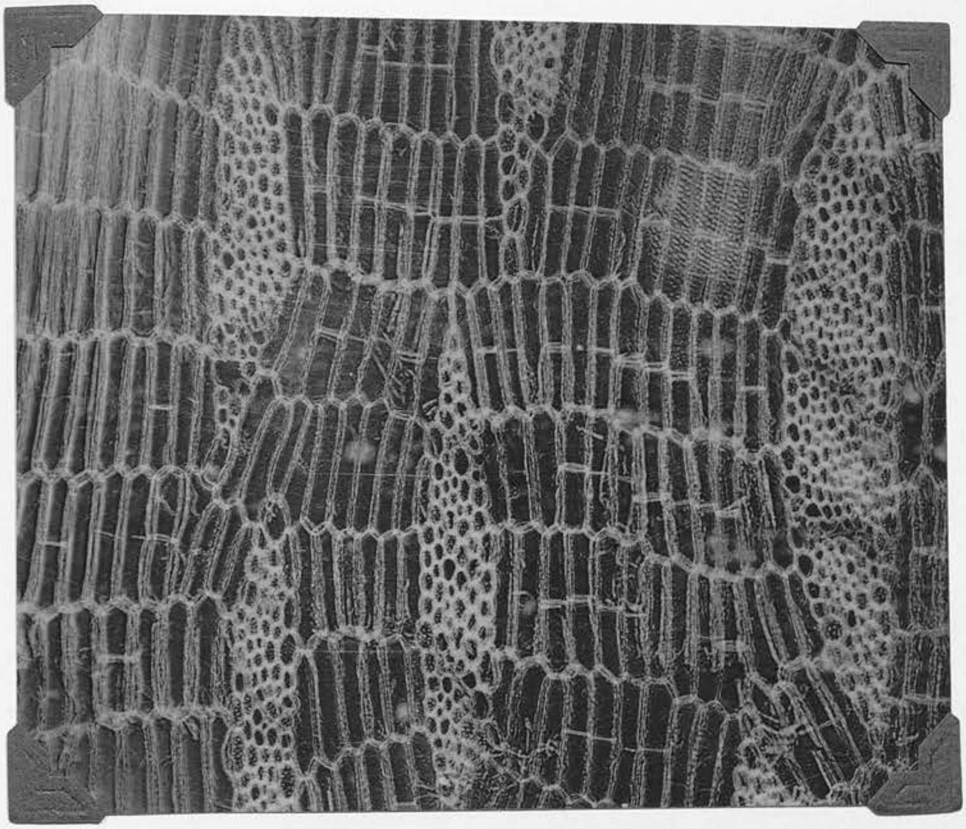


PLATE II

Erythrina stricta.

MACARANGA Thouars.

(Plates 12 - 16)

Macaranga is a large genus (family Euphorbiaceae) comprising about 24 species occurring all over India, Burma and Ceylon. Gamble has described three species in the Flora of Madras Presidency. They are (1) *Macaranga indica* (2) *Macaranga flexuosa* (3) *Macaranga peltata.* These trees occur in the hills of the Western Ghats, Malabar, N.Circars and Cuddapah. The species under study here is *Macaranga peltata.*

Macaranga peltata Muell Arg. (M. Roxburghii Wight) is known as 'Vatta' in Malayalam and 'Vattakanni' in Tamil. It is a middle-sized, resinous, quick growing tree with pale bark and stout branches.

Leaves alternate, large, orbicular, broadly peltate, with large stipules. Blade 4-10 in. long, many ribbed at the base, margin minutely toothed. Petiole as long as or longer than the lamina.

Panicles rusty-tomentose, arising in the axil of broad bracts.

Flowers dioecious with broad close bracts; male flowers are minute and are in clusters enveloped in cup-like bracts.

The Calyx three lobed

Corolla absent

Stamens 2-3. The female flowers are few

Ovary 1-celled, style lateral, peltate

Capsule is less than $\frac{1}{4}$ of an inch in diameter.

Seeds globose with brown testa.

Distribution.

The tree is largely distributed in Travancore-Cochin state on the slopes of the Western Ghats up to a height of 3000 ft.

The Timber.

The wood is whitish when freshly cut, pale brown in colour when dry. Heartwood cannot be distinguished by colour. The wood is of even texture and close straight grain.

Growth-rings are invisible to the naked eye and indistinct with hand lens.

Pores are few, visible to the naked eye, mostly in radial groups, evenly distributed.

Soft tissue not visible under the lens.

Rays fine not visible in transverse section, but clearly seen under the lens on the radial section.

Microscopic features.

Growth-rings are very undulate, clearly distinguished, marked by a zone of radially flattened cells 4-8 rows wide.

Vessels medium-sized and moderately large, 100-255 μ in diameter, moderately few, 7-9 per sq:mm., mostly occurring in radial groups of 2-5 or solitary. They are oval in shape and are evenly distributed throughout the ring. Vessel members medium-sized and moderately long, 600-846 μ in length, medium thin walled, cylindrical, attenuately tailed. Tyloses present.

Perforations. Simple, oblique

Intervascular pits alternate and small. They are round or elliptical when few, but polygonal when numerous. The diameter of the pit is 4-7 μ. The pit aperture is narrow and slitlike.

Pits leading to the ray and parenchyma cells are slightly larger than the intervascular pits, variable in shape, oval or polygonal with large orifice and with a narrow border. The diameter of the pits vary from 8-11 μ.

Parenchyma mostly apotracheal occurring as sparse odd cells scattered among the fibres. Paratracheal parenchyma also is present scanty as laterally compressed cells around the vessels.

Fibres thin-walled, aligned in regular radial rows. The length of the fibre varies considerably. The fibres are extremely short, very short, moderately short or medium-sized, 350-1120 μ long, diameter 11-24 μ.

Rays normally spaced, fairly close or close, 7-20 per mm., uniseriate, mostly biseriate or very rarely triseriate, composed of upright cells and procumbent cells. Biseriate parts are scarcely wider than the uniseriate parts. The rays are extremely fine, very fine or moderately fine, 11-44μ wide, formed by 1-5 cells. The height of the ray is 330-3030μ, formed by 13-60 cells. The rays are heterogeneous Type I Kribs. Large crystals are present in chambers. Gum deposits abundant.

Discussion.

Macaranga indica Wight and Macaranga flexuosa Wight are the other two species of the genus that occur in S. India. The wood anatomy of these trees has not been studied.

The anatomy of the wood of three non-Indian species of the genus was observed from the permanent slides kept at the Imperial Forestry Institute, Oxford, and recorded below, (the numbers refer to the characters specified in the index card Plate 28). Those characters are contrasted with those of M. peltata.

M. hypoleuca	6 17 18 28 35 43 44 45 46 48 51 52 54 76 77 78
M. puncticulata	6 17 18 28 29 43 44 51 52 76
M. barteri	6 17 18 28 35 36 43 44 45 46 51 54 62 64 78
M. peltata	6 18 28 43 44 45 46 62 64 75 78

M. peltata and M. bateri show great similarity in the anatomical structure as noted above.

The numbers of vessels per sq:mm. (character 17) is fewer than 5 in all the three species whereas in M. peltata it is 7-9 per sq:mm.

The distribution of the parenchyma alone forms a distinguishing character. The apotracheal banded parenchyma (character 51) occurs in all except M. peltata where the parenchyma is scattered.

Thus M. peltata is separated from the other three species noted above.

MACARANGA PELTATA.

PLATE 12.

a - c.	Vessel members x 150
d.	R.L.S. x 150 showing the intervascular pits and pits to parenchyma.
e.	Intervascular pits x 950
f.	Pits to parenchyma x 950

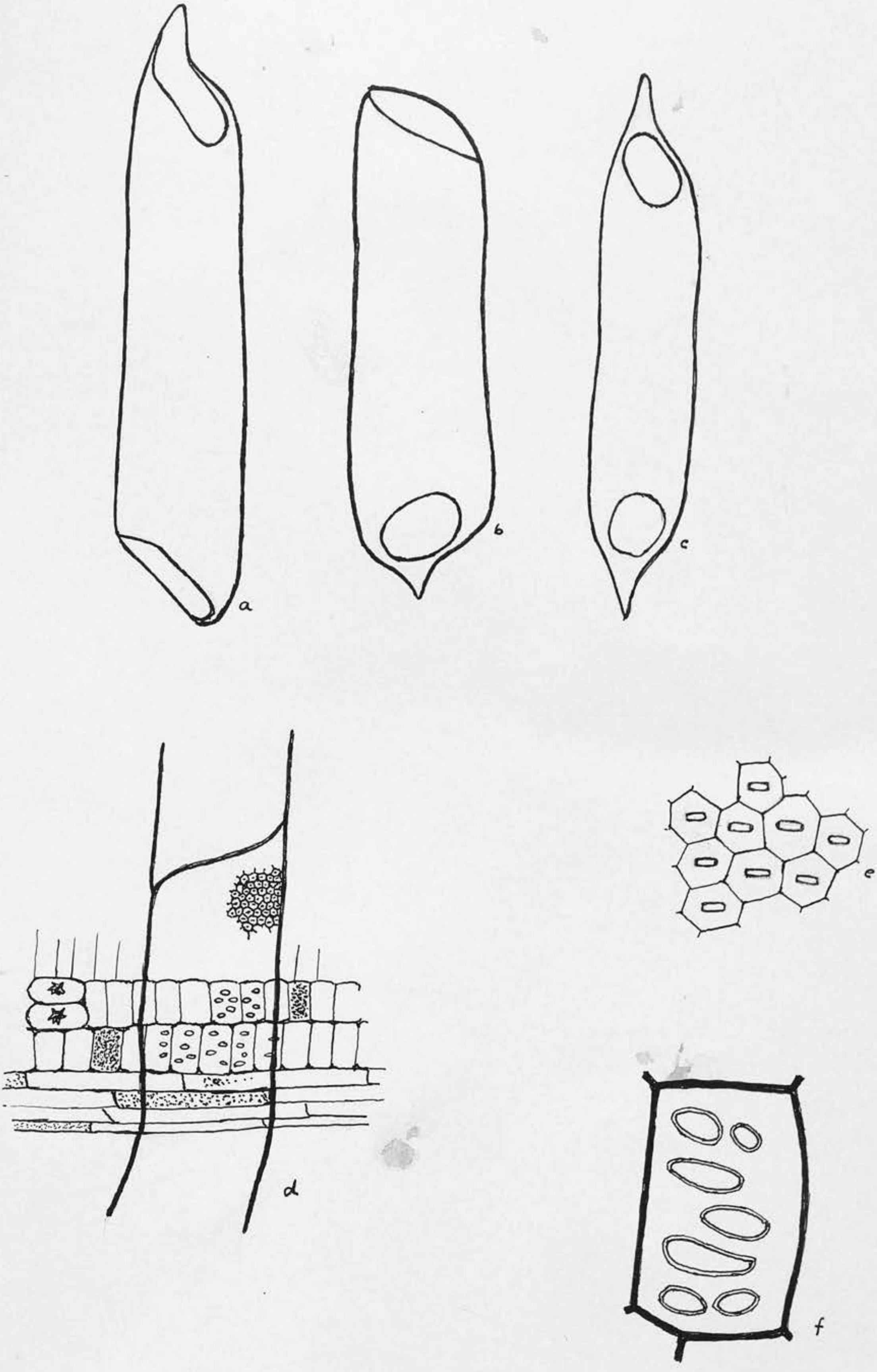
PLATE 13.

g - i.	Rays (T.L.S) x 150
j - k.	Fibres x 150

PLATE 14. T.S. x 20

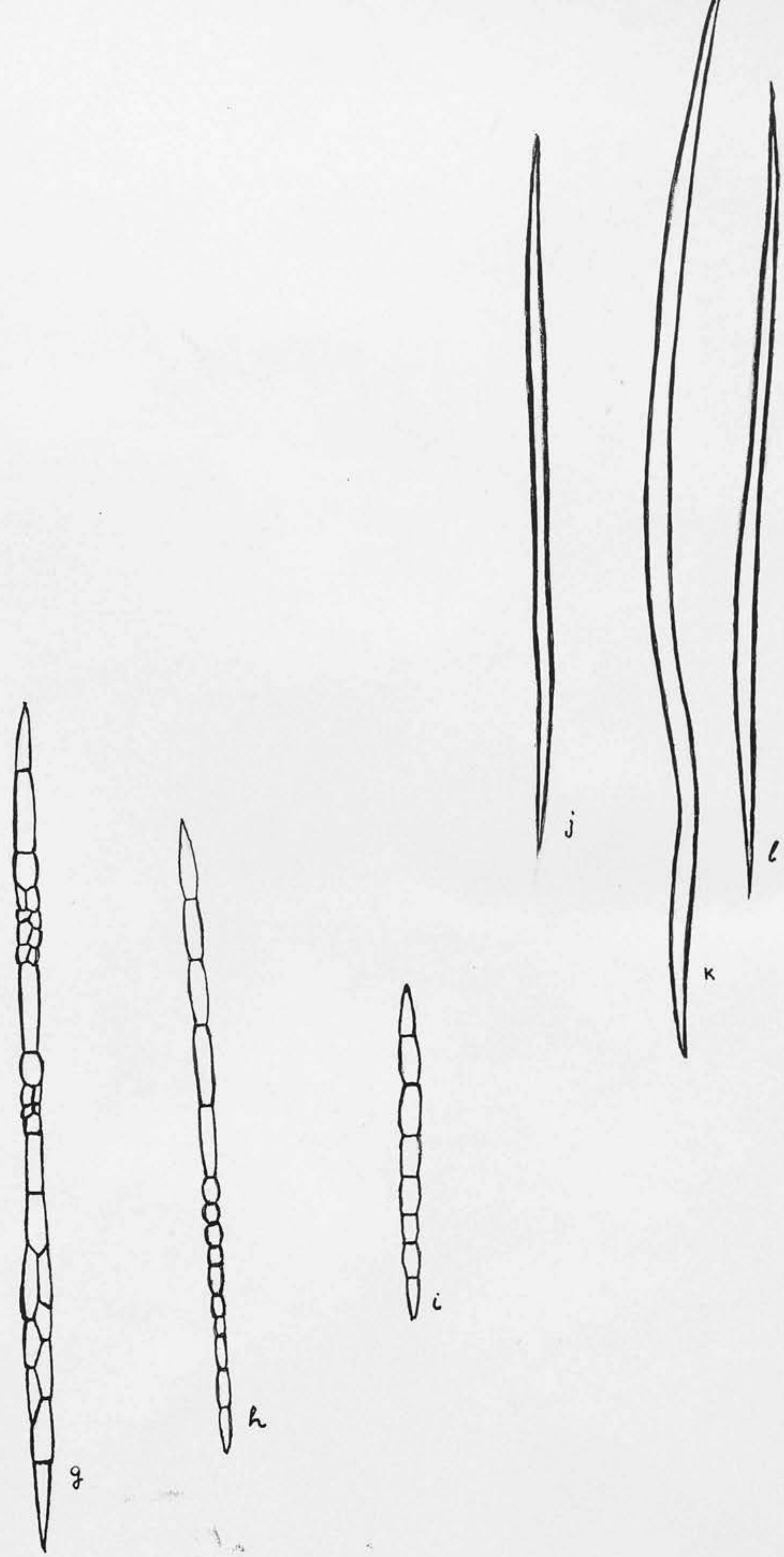
PLATE 15. T.S. x 50

PLATE 16. T.L.S. x 100



Macaranga peltata.

PLATE 13



Macaranga peltata.

PLATE I4

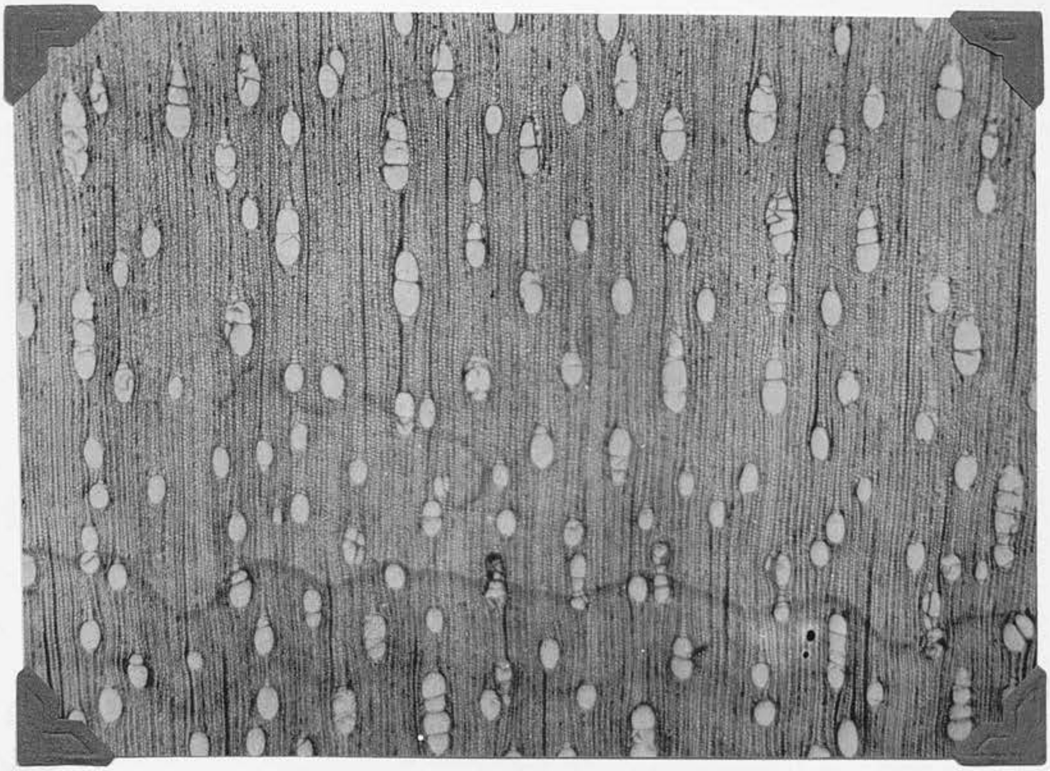
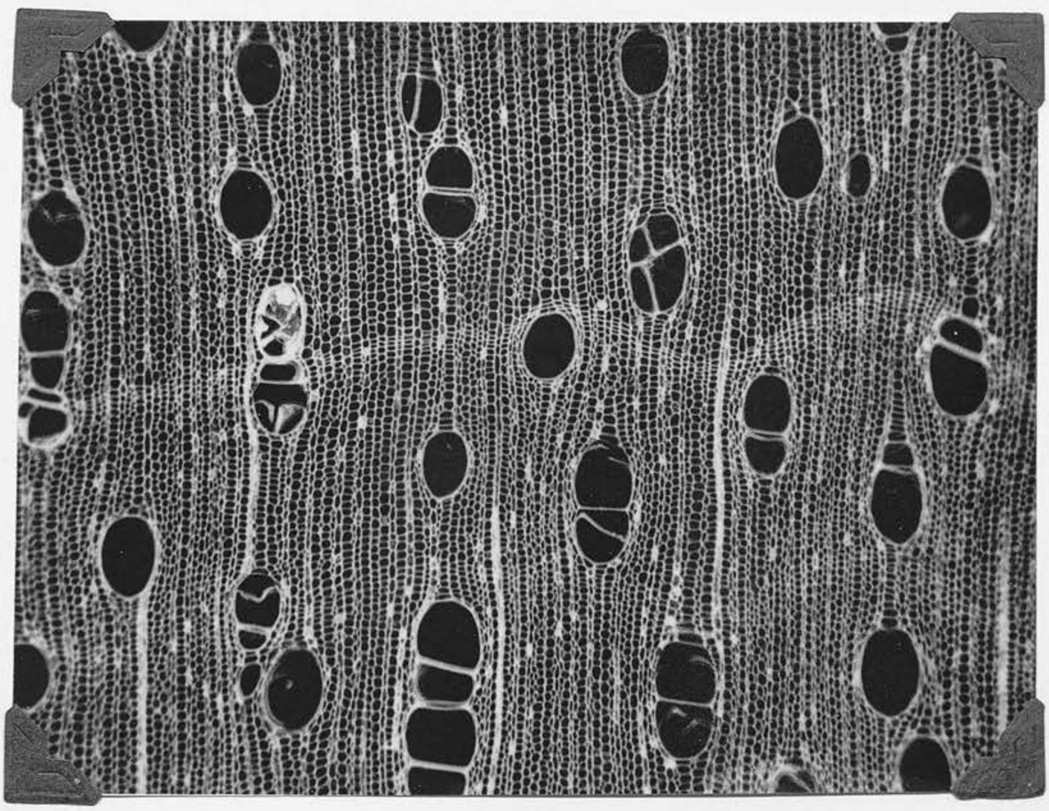


PLATE I5



Macaranga peltata.

PLATE 16

Macaranga peltata.

TABERNAEMONTANA Plum.

(Plates 17 - 21)

This genus (family Apocynaceae) comprises many species, trees or shrubs occurring all over Deccan, Western Ghats, Chitagong, Andamans etc. Tabernaemontana dichotoma, the species under investigation here is common in Travancore.

Tabernaemontana dichotoma Roxb. is a small evergreen tree of very slow growth, known as 'Koonampala' in Malayalam. The bark is grey with much latex. The stem often branches dichotomously, branches stout, buds resinuous.

Leaves opposite, elliptic-oblong, blade 4-9 by 1-2 in. Midrib very stout, nerves 16-24 pairs. Margin is entire. Petiole $\frac{1}{2}$ - 1 in. long.

Inflorescence cymose. Peduncles 2-5 in. long; bracts not present.

The Flower is slightly scented.

Calyx 5-lobed, very thick with semicircular lobes.

Corolla tubular, $\frac{3}{4}$ - 1 in. long, and 1-2 in. diameter. The base swollen and yellow, limb white, mouth contracted, lobes broadly oblong, falcate, obtuse.

Stamens inserted half-way down the tube with very short filament.

Ovary with two distinct carpels; Style

2-lobed, ovules many.

Fruit of two more or less fleshy follicles, orange in colour, 2 in. long

Seeds many, buried in the pulp.

Distribution The tree is common in Malabar, Travancore and Ceylon. It is found only in the moist regions.

The Timber is strong and light and was formerly used in carving.

The Timber

The wood is pale yellow when freshly cut, but turns slightly grey when dry. Heartwood cannot be distinguished by colour. The wood is of even texture and close straight grain.

Growth rings are invisible to the naked eye and scarcely distinguishable even with a hand lens.

Pores are numerous, small, not individually visible to the naked eye, evenly distributed.

Soft tissue not visible under the lens.

Rays fine, clearly seen under the lens in the radial and transverse sections. In tangential section they form fine flecks.

Microscopic features

Growth rings are marked by a zone of slightly larger vessels in the early wood.

Vessels very small, moderately small, or medium sized, 45-125μ in diameter, numerous to very numerous, 86-45 per sq:mm., round or oval in shape, occurring in radial or rarely in tangential groups of 2-5 very occasionally solitary. Throughout the ring the vessels are more or less evenly distributed except at the outer margin of the ring where the vessels are fewer and slightly smaller than those at the inner margin. The vessel members are medium sized to moderately long, 625-880μ long, medium, thin-walled, cylindrical, abruptly or attenuately tailed.

Perforations. Simple, oblique, very small, smaller than the diameter of the vessels.

Intervascular pits alternate, numerous, very small to minute, oval with horizontal orifice.

Pits leading to ray and parenchyma cells are similar to the intervascular pitting.

Parenchyma apotracheal as scattered cells. Crystals of large size are present.

Fibres numerous septate libriform, arranged in regular radial rows. They are medium-sized to moderately long, varying from 1000-1935μ and the diameter from 15-35μ. Walls moderately thick with oblique pits confined to the radial walls.

Rays widely or normally spaced, 3-7 per mm. They are mostly multiseriate with uniseriate ends. The multiseriate part is formed of small procumbent cells and the uniseriate part of 1-5 rows of upright cells. There are also uniseriate rays consisting of large upright cells. The rays are very fine, moderately fine or medium sized varying from 22-60μ in width, formed by 1-5 cells. The height of the ray is from 250-1060μ formed by 10-30 cells. They are heterogeneous Type IIA Kribs. Large crystals are present in most of the upright cells of the ray. Marginal cells are very conspicuous sheath cells.

Discussion.

There are only two tree species which belong to the genus Tabernaemontana in S. India. (1). They are _T. dichotoma_ Roxb. and _T. heyneana_ Wall. The wood anatomy of the latter has not been studied yet.

From the collections of permanent slides at the Imperial Forestry Institute, Oxford the anatomical characters of the wood of another species of this genus was observed. This was _Tabernaemontana citrifolia_ Linn. which occurs in Central America and West Indies, Record and Hess (15). The microscopic characters of the wood of the two species are recorded below (the numbers refer to the character specified in the index card - Plate 28).

T. citrifolia 6 10 19 20 21 23 28 35 36 43 86

T. dichotoma (2) 6 10 19 21 23 28 35 39 46 61 75

The number of rays in _T. dichotoma_ is 3-7 per mm., whereas it is more than 12 in _T. citrifolia._

Sheath cells rarely occur in _T. dichotoma_ and they are absent in _T. citrifolia._

Large crystals which are present in _T. dichotoma_ are absent in _T. citrifolia._

These differences in the anatomical structure are sufficient to separate _T. dichotoma_ from _T. citrifolia._

TABERNAEMONTANA DICHOTOMA

PLATE 17.

a - c. Vessel members x 150

d. R.L.S x 150 showing the intervascular pits and pits to parenchyma

e. Intervascular pits x 950

f. Pits to parenchyma x 950

PLATE 18.

g - i. Rays (T.L.S) x 150

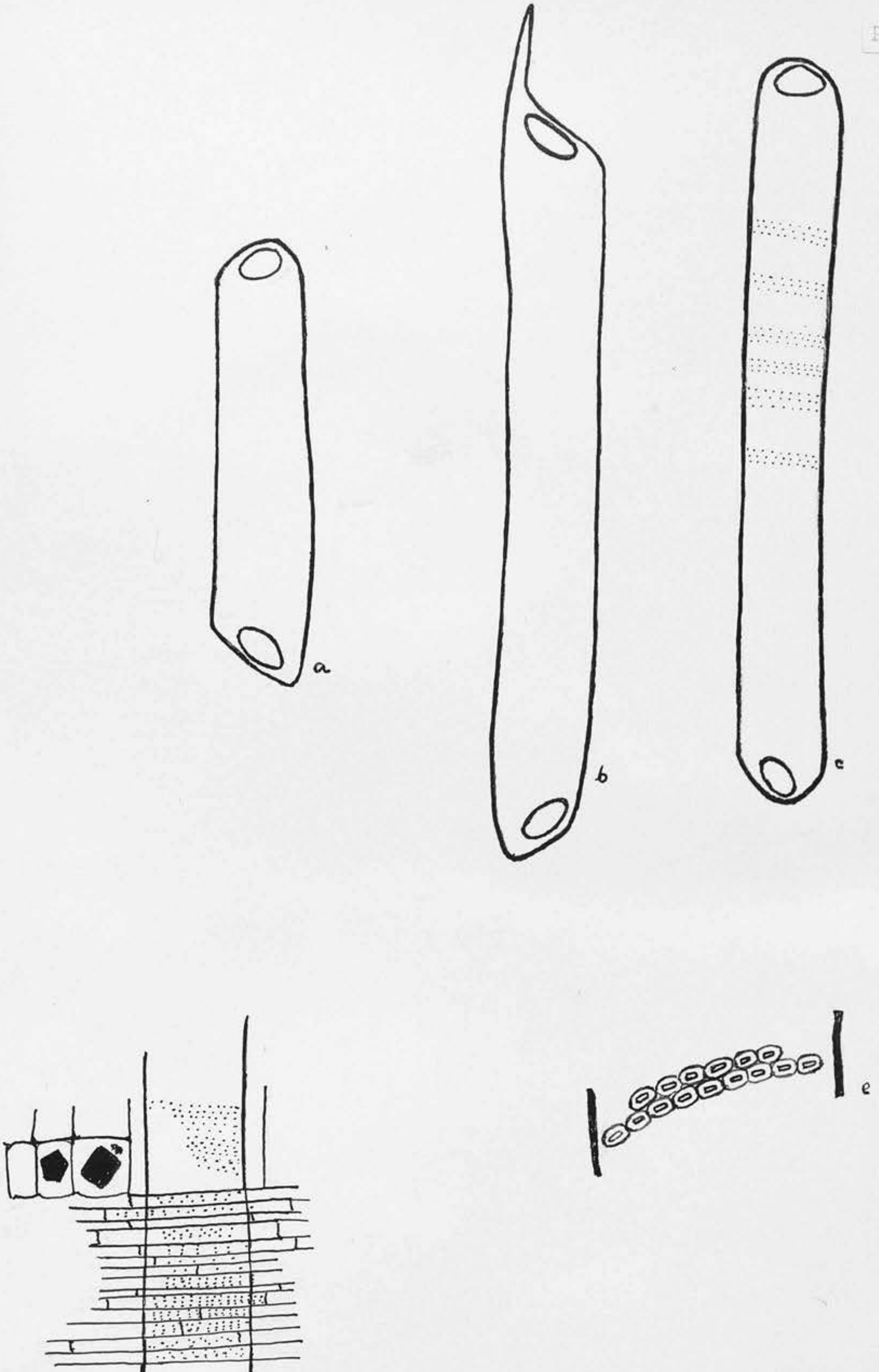
j - k. Fibres x 150

PLATE 19. T.S. x 20

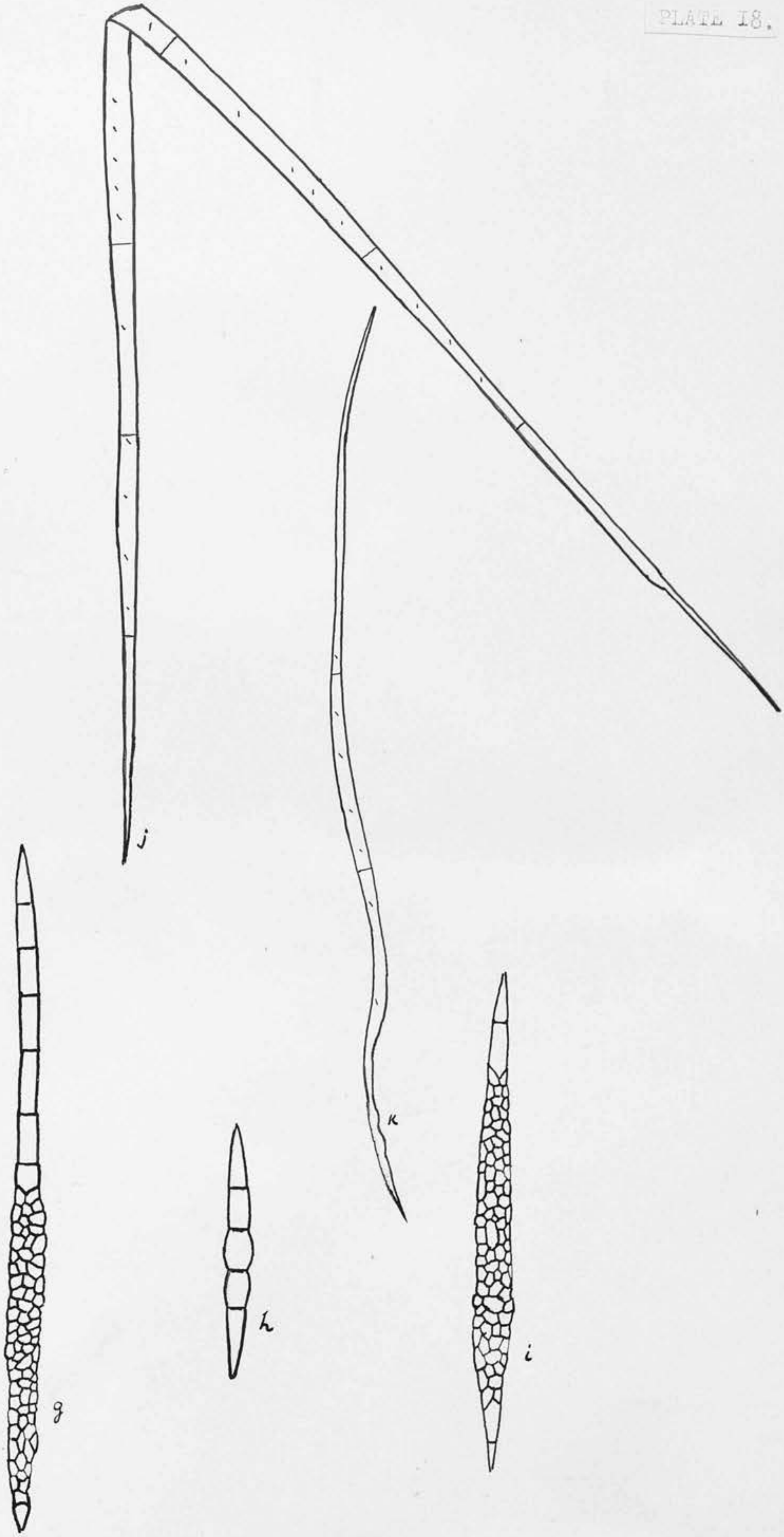
PLATE 20. T.S. x 50

PLATE 21. T.L.S. x 100

PLATE 17.



Tabernaemontana dichotoma.



Tabernaemontana dichotoma.

PLATE I9.

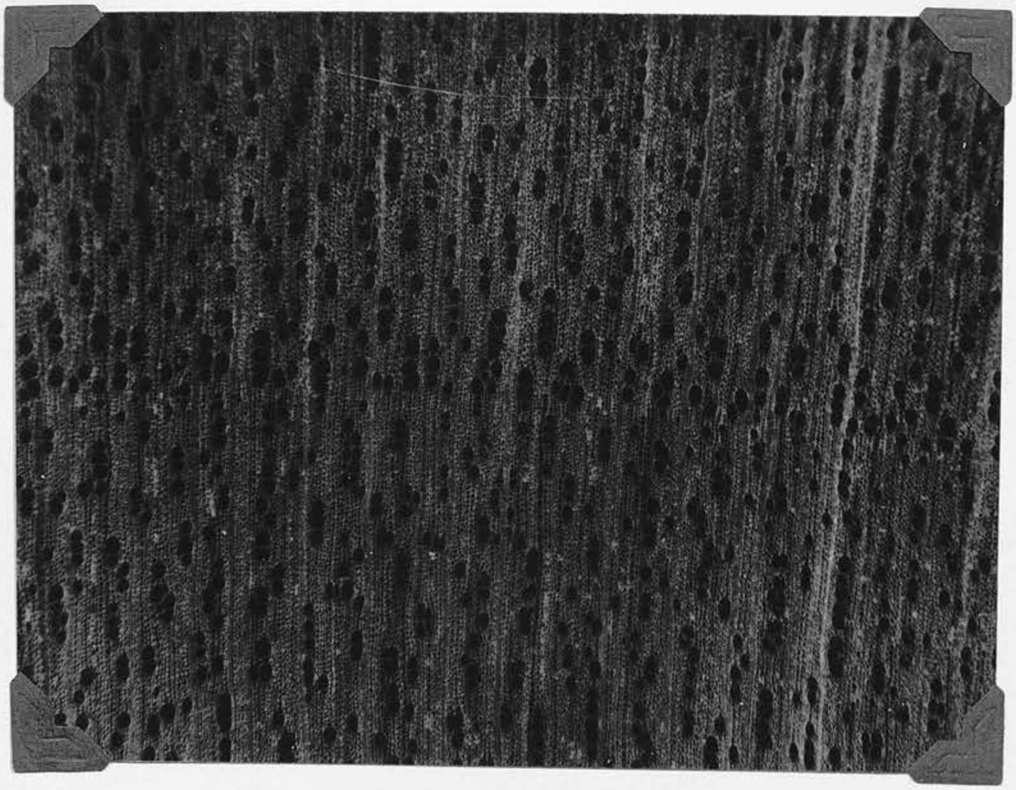
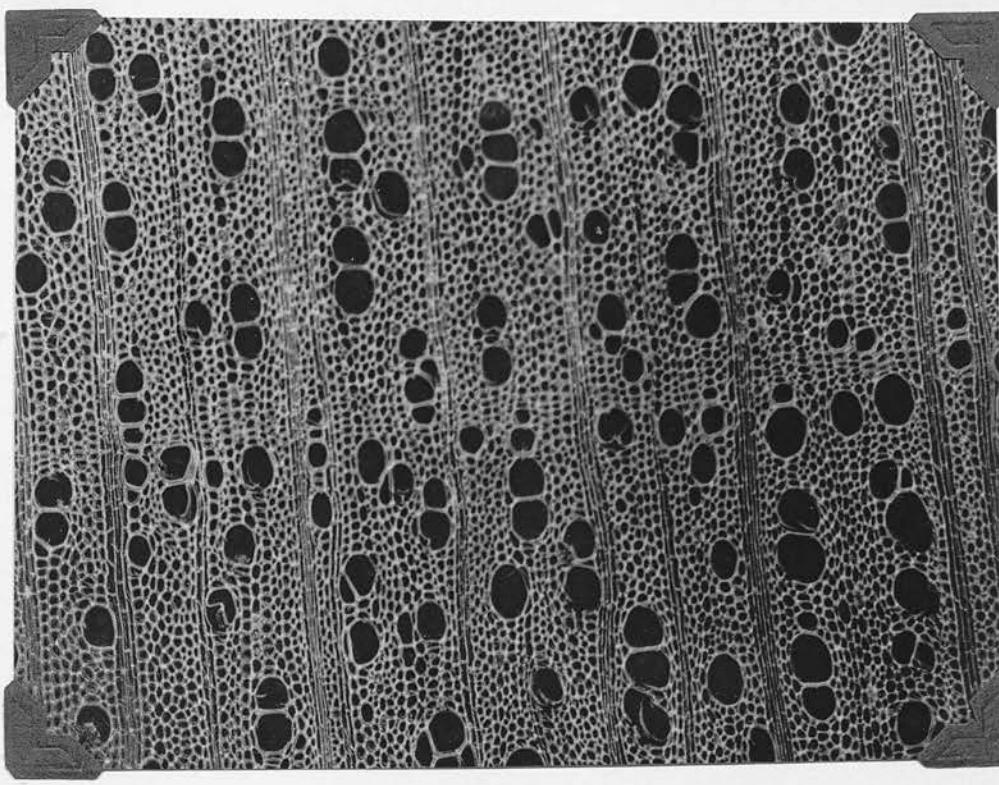
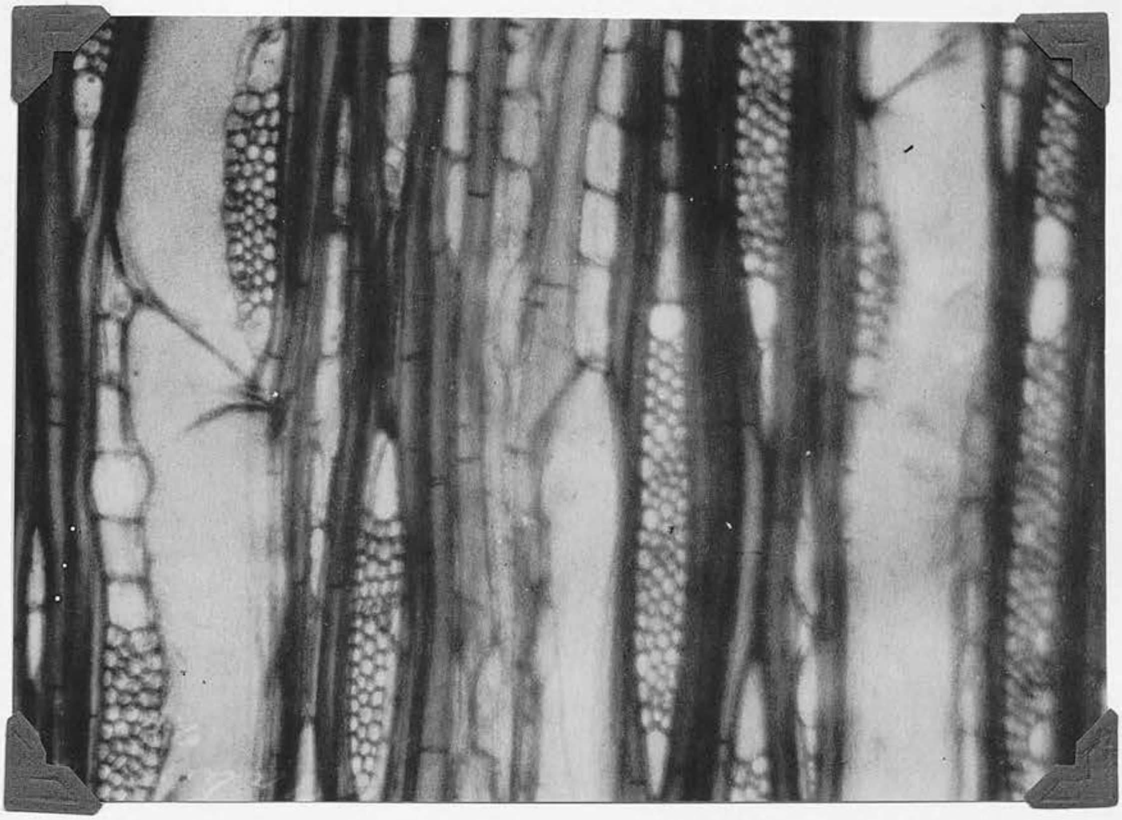


PLATE 20.



Tabernaemontana dichotoma.

PLATE 2I.



Tabernaemontana dichotoma.

ANACARDIUM Linn.

(Plates 22 - 27)

The genus Anacardium (family Anacardiaceae) consists of several species. Anacardium occidentale, the species under study here was introduced into India from Brazil about 400 years ago and it has become naturalised in the regions on the west coast of India.

Anacardium occidentale Linn. is a small or middle-sized, drought resistant tree generally 20-40ft in height. It is known as "Paringimavu" or "Casuvan mavn" in Malayalam. The bark of the tree is thick, rough and scaly. The tree produces stout branches which spread in every direction.

Leaves alternate, simple, coriaceous, obovate 5-6 in. in length. The leaves are narrowed towards the base and have an entire margin. Both the upper and lower surface glabrous. Secondary veins very conspicuous, about 8-12 pairs. The petiole is $\frac{1}{2}$ - $\frac{3}{4}$ in. long.

Flowers small, in large terminal panicles with prominent bracts deeply fine-lobed, lobes lanciolate.

Calyx slightly hairy

Corolla pale yellow in colour streaked with pink, linear lanceolate, revolute, slightly hairy on the outside.

Stamens generally 10, one longer which is always fertile, and the rest either fertile or sterile.

Ovary obovate, 1-celled with a filiform excentric style having a very small stigma. The ovule is solitary, ascending from a lateral funicle.

Fruit a kidney-shaped nut seated on a fleshy thick aril formed by the enlargement of the torus and the top of the peduncle. It is known as the "Cashew Apple".

The pericarp of the fruit contains sacs filled with acrid oil.

Seeds reniform

Distribution. The tree is common in Tropical America from Mexico and the W.Indies to Peru and Brazil. It is cultivated in the coastal regions of S. Africa, Madagascar, India, Ceylon and the Philipines. In India it is cultivated in the west coast, Ratnagiri, North Kanara districts in Bombay, Goa, South Kanara, Malabar districts in Madras and Travancore-Cochin and to a lesser extent in Bengal, Orissa and Mysore.

Economic Importance. The tree is cultivated mainly for its nuts which are used as dessert. From the pericarp of the fruit a dark brown viscous oil is obtained, which is used for various purposes. The 'cashew apple' is soft and juicy and very sweet when ripe. It is edible and from it a delicious beverage is made. The tree also yields a pale yellowish-red gum which exudes in stalactiform masses from the stem and branches. The wood is used for making packing cases, for boat building and for charcoal.

The Timber.

The sapwood is pale brown when freshly cut, turning pink-brown when dry. The zone of the heartwood can easily be distinguished by the dark brown colour when fresh as well as dry. The wood is of even texture with moderately close and straight grain.

Growth rings are invisible even with hand lens

Pores few, visible to the naked eye, evenly distributed. In the longitudinal section they are seen as deep groves.

Soft tissue not visible under the lens.

Rays fine, clearly seen under the lens in transverse section, very conspicuous in the radial section. In the tangential section they form numerous fine flecks.

Microscopic features.

Growth rings very inconspicuous, distinguished only with great difficulty. They are marked by a zone of radially flattened cells at the outer margin of the ring.

Vessels medium-sized to moderately large, 110-270μ in diameter. They are moderately few, 5-6 per sq:mm; oval in shape, mostly occurring in groups of 3 or 4 and sometimes solitary. Throughout the ring the vessels are fairly evenly distributed. The vessel members are 360-460μ long, medium sized, medium thin walled, cylindrical, abruptly or attenuately tailed.

Perforations simple, oblique

Tyloses are abundant

Intervascular pits alternate, numerous. The pits are polygonal with small elongated lens shaped aperture. The diameter of the pit is from 9-12μ.

Pits leading to ray and parenchyma cells are few, larger than the intervascular pits, very variable in shape, orbicular or oval with narrow border and very wide orifice. The diameter of the pit is 10-14μ.

Parenchyma predominantly paratracheal, vasicentric.

Fibres non-septate, aligned in regular radial rows. The fibres are very short or moderately short, vary from 600-735μ in length, diameter 22-28μ, walls thin with oblique pits with slit-like orifices confined to the radial walls.

Rays normally spaced or fairly close, 9-13 per mm., 1-3 seriate, but mostly biseriate, with uniseriate tiers longer than the biseriate parts.

The biseriate parts occur at one or two places in a ray. The rays are moderately fine to medium-sized, varying from 30-60μ in width and 2-30 cells high measuring 110-670μ. The rays are heterogeneous Type IIB Kribs. Ray cells are thin-walled shortly rectangular or square, mostly filled with gum like substance.

Discussion

In India no other species of the genus Anacardium is known to occur. The general characters of A. occidentale have been described by R.W. Hess (10). The observations made by him more or less agree with those made above excepting in certain details. Hess has not recorded the occurrence of tyloses in the specimen of A. occidentale he has examined. The colour of the wood according to him is "heartwood light greyish-brown, often with slight orange cast or yellow streaks not distinct from lighter coloured sapwood". This differs from what is noted above.

The anatomical features of A. occidentale are contrasted with those of A. excelsum. A slide of A. excelsum (F.P.R.L 15749) was examined and the observations made were compared with those made by Hess.

The details shown in the slide do not fully agree with Hess's description of A. excelsum.

Hess (10) mentions "thin walled tyloses abundant in the heartwood". The slide does not show tyloses. According to Hess the rays are very numerous "about 70 per mm". This is probably a misprint for "about 7 per mm" which agrees with his photograph and the slide. In _A. occidentale_ as already described, tyloses occurs abundantly while the rays are fairly close, 9-13 per mm.

The size of the vessels and the structure of the rays in _A. occidentale_ and _A. excelsum_ serve to separate the two species. The vessels in _A. occidentale_ are medium-sized to moderately large varying from 110-270μ in diameter and in _A. excelsum_ they are large to very large, 250-380μ in diameter. In _A. occidentale_ uniseriate rays occur very frequently, biseriate rays mor common with very short biseriate tiers and long uniseriate tiers on either end of the ray. In _A. excelsum_ there are very few uniseriate rays. The biseriate rays are biseriate almost throughout the entire height of the ray with very short uniseriate tiers on either end.

A. occidentale	A. excelsum
Vessels. Medium-sized to moderately large 110-270μ in diameter	Vessels large to very large 250-380μ in diameter
Tyloses. Abundant	Tyloses. Abundant
Intervascular pits 9-12μ in diameter	Intervascular pits 12-17μ in diameter
Rays fairly close, 9-13 per mm.	Rays 5-7 per mm.
Uniseriate rays occur frequently.	Very few uniseriate rays
Biseriate tiers very short with very long uniseriate tiers on either end of the biseriate ray.	Biseriate almost throughout the entire height of the ray with very short uniseriate tier on either end.

ANACARDIUM OCCIDENTALE

PLATE 22.

a - c. Vessel members x 150

d. R.L.S. x 150 showing the intervascular pits and pits to parenchyma

e. Intervascular pits x 950

f. Pits to parenchyma x 950.

PLATE 23.

g - i. Rays (T.L.S) x 150

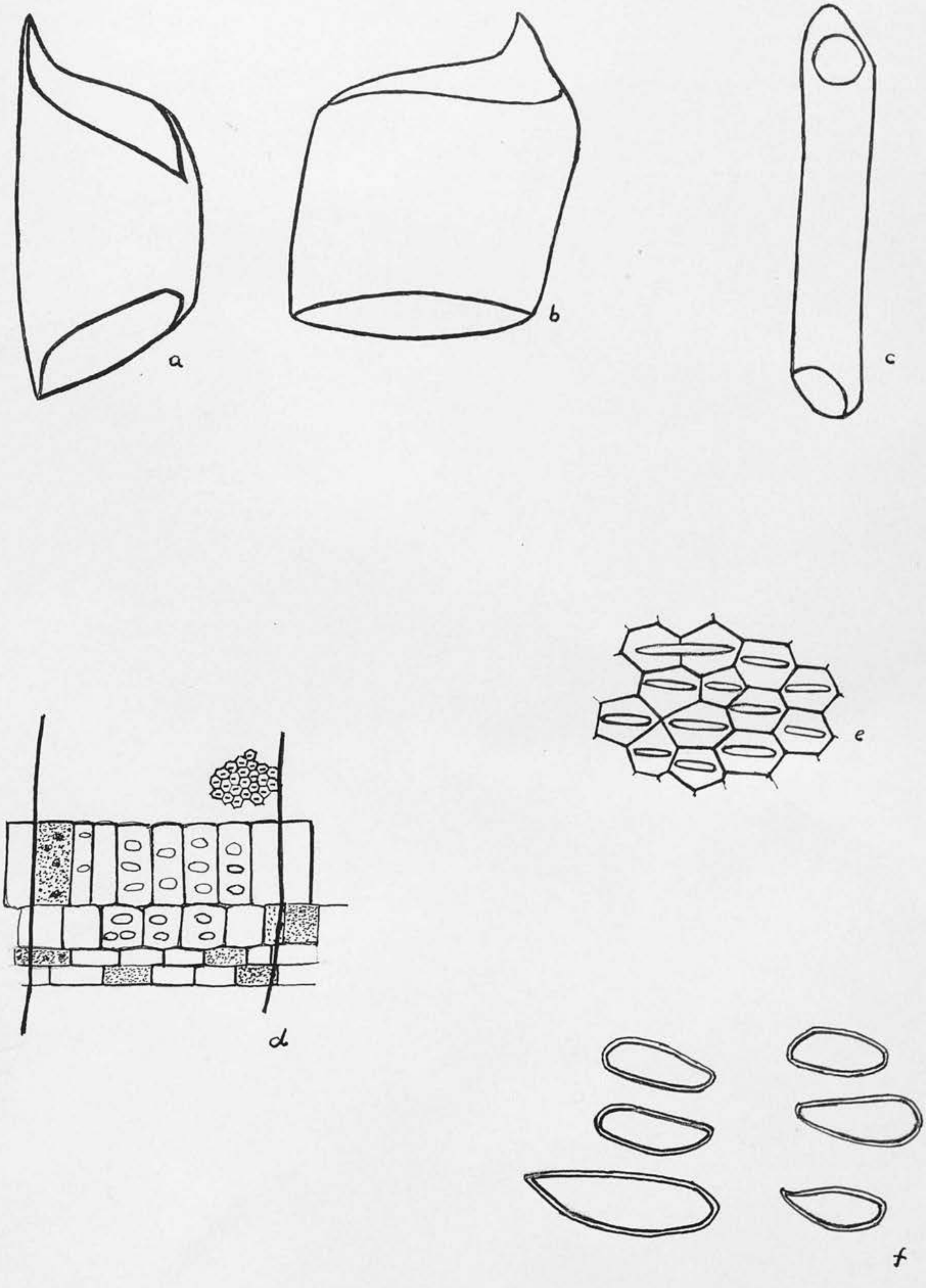
j - l. Fibres x 150

PLATE 24. T.S. x 20

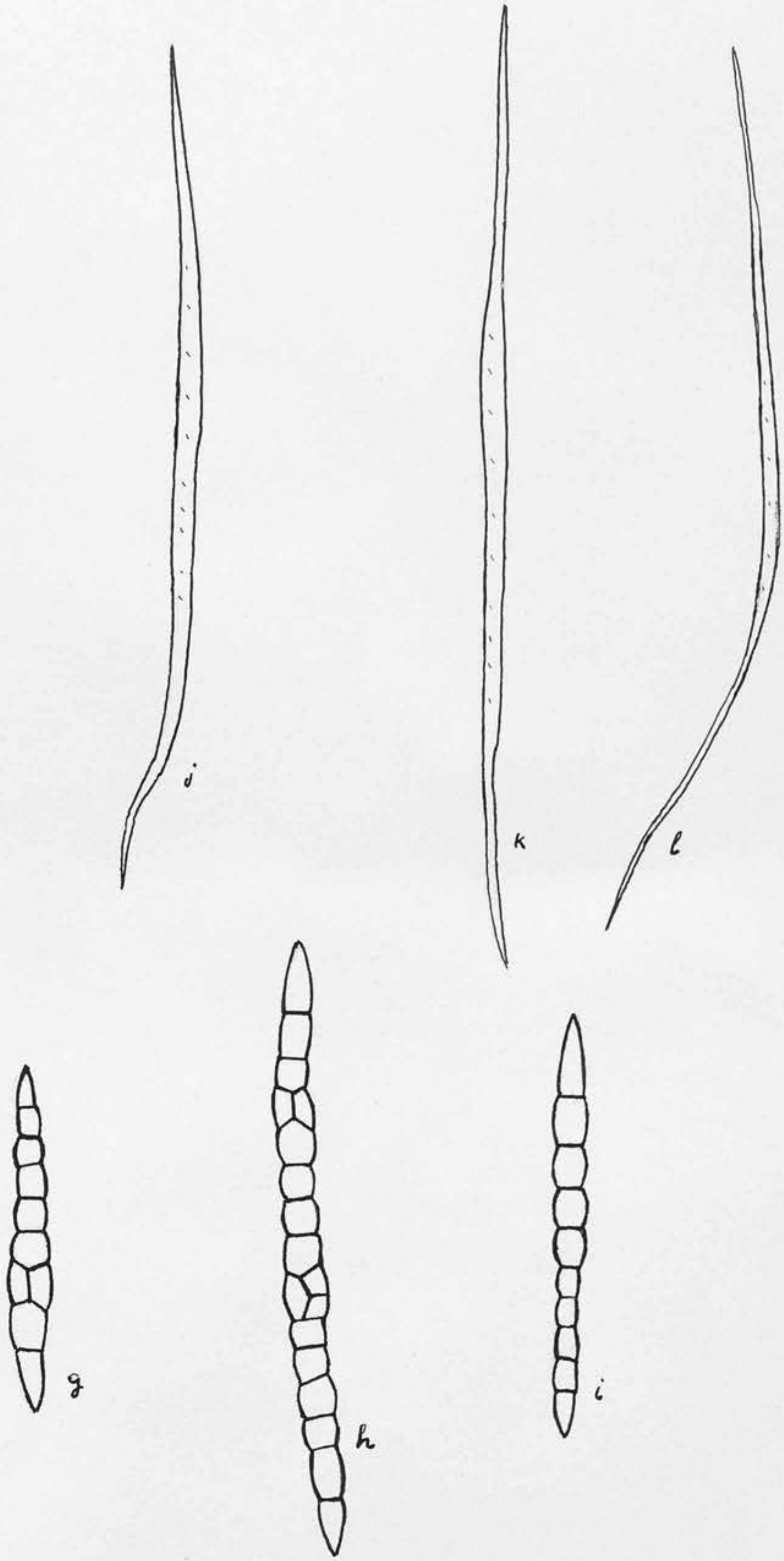
PLATE 25. T.S. x 50

PLATE 26. T.L.S. x 100

PLATE 27. T.S. x 100 showing tyloses.



Anacardium occidentale.



Anacardium occidentale.

PLATE 24.

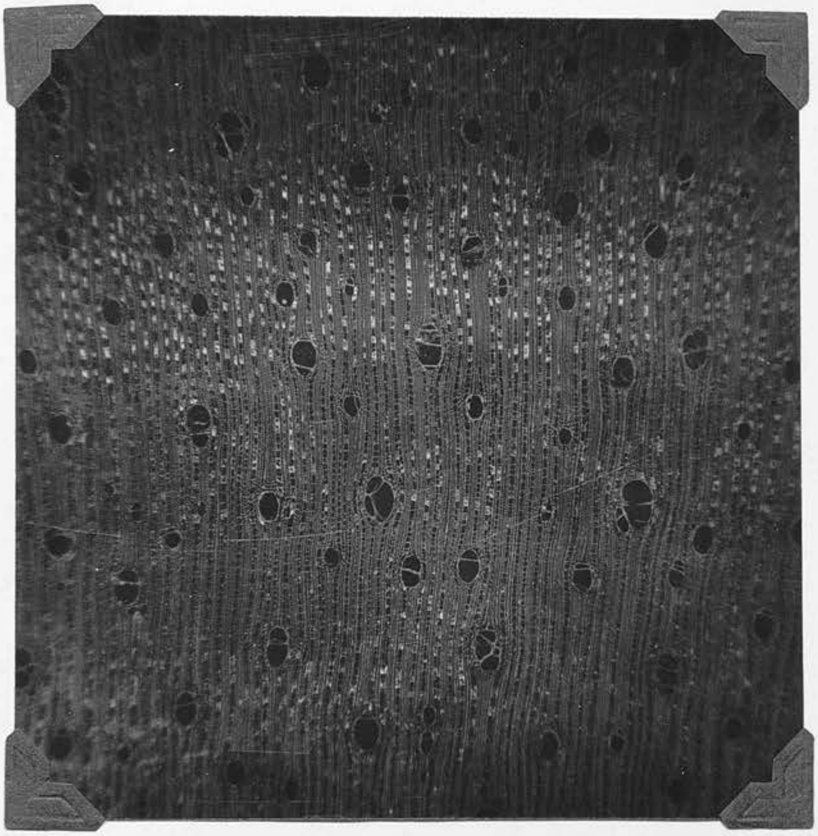
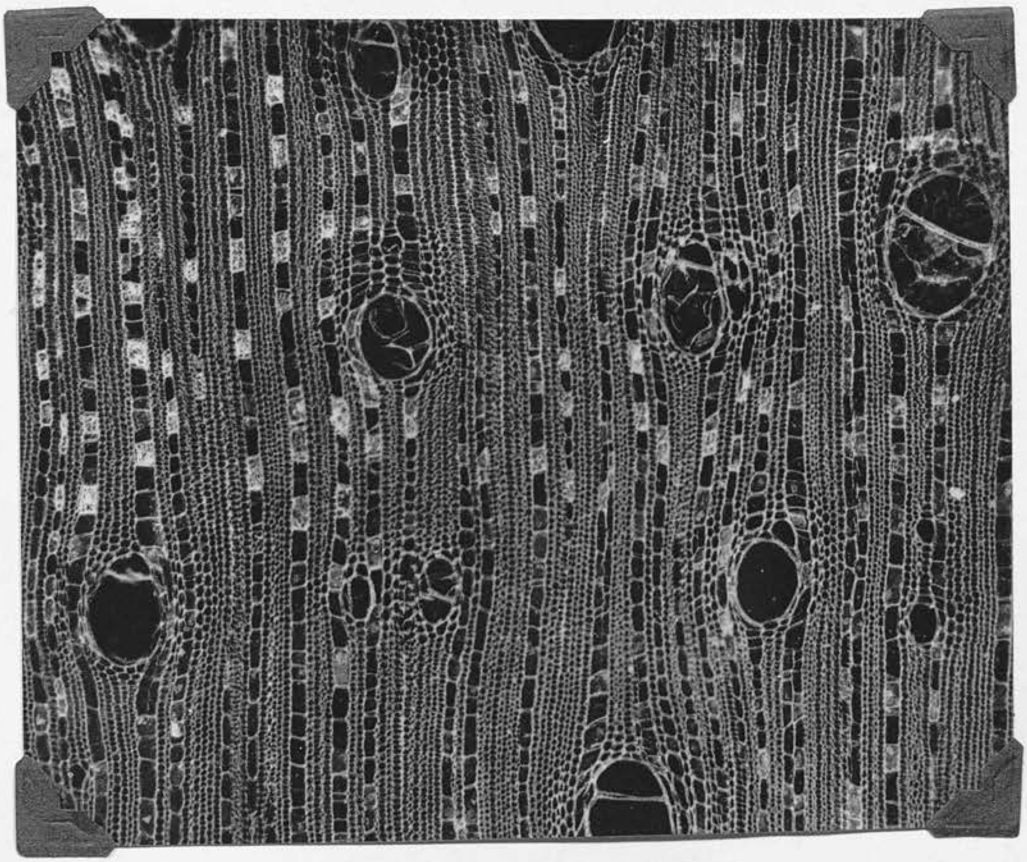


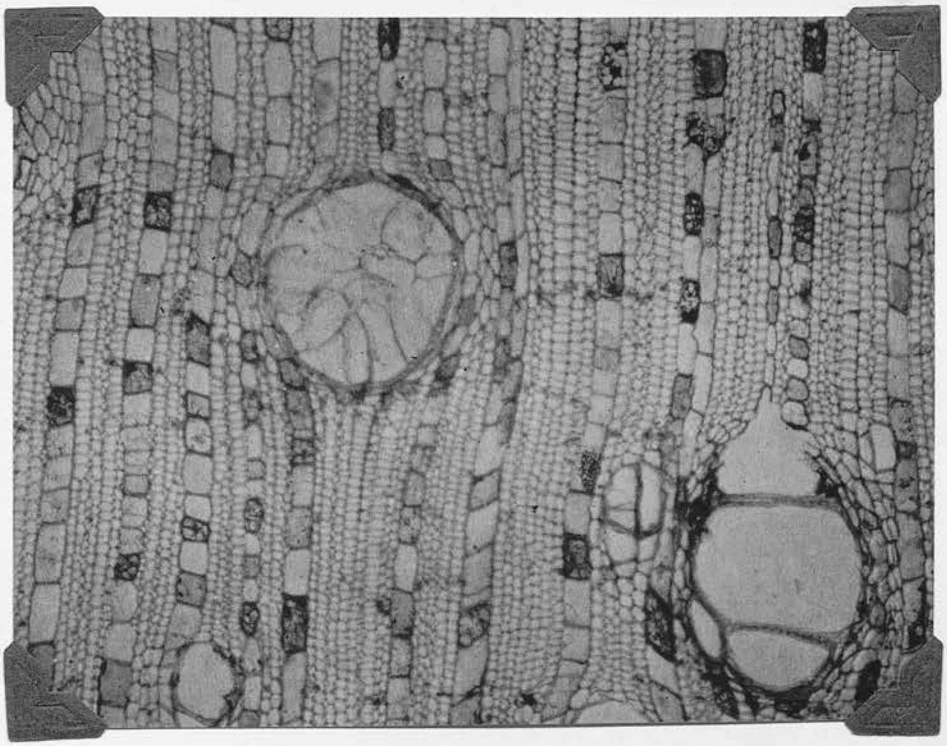
PLATE 25.



Anacardium occidentale.

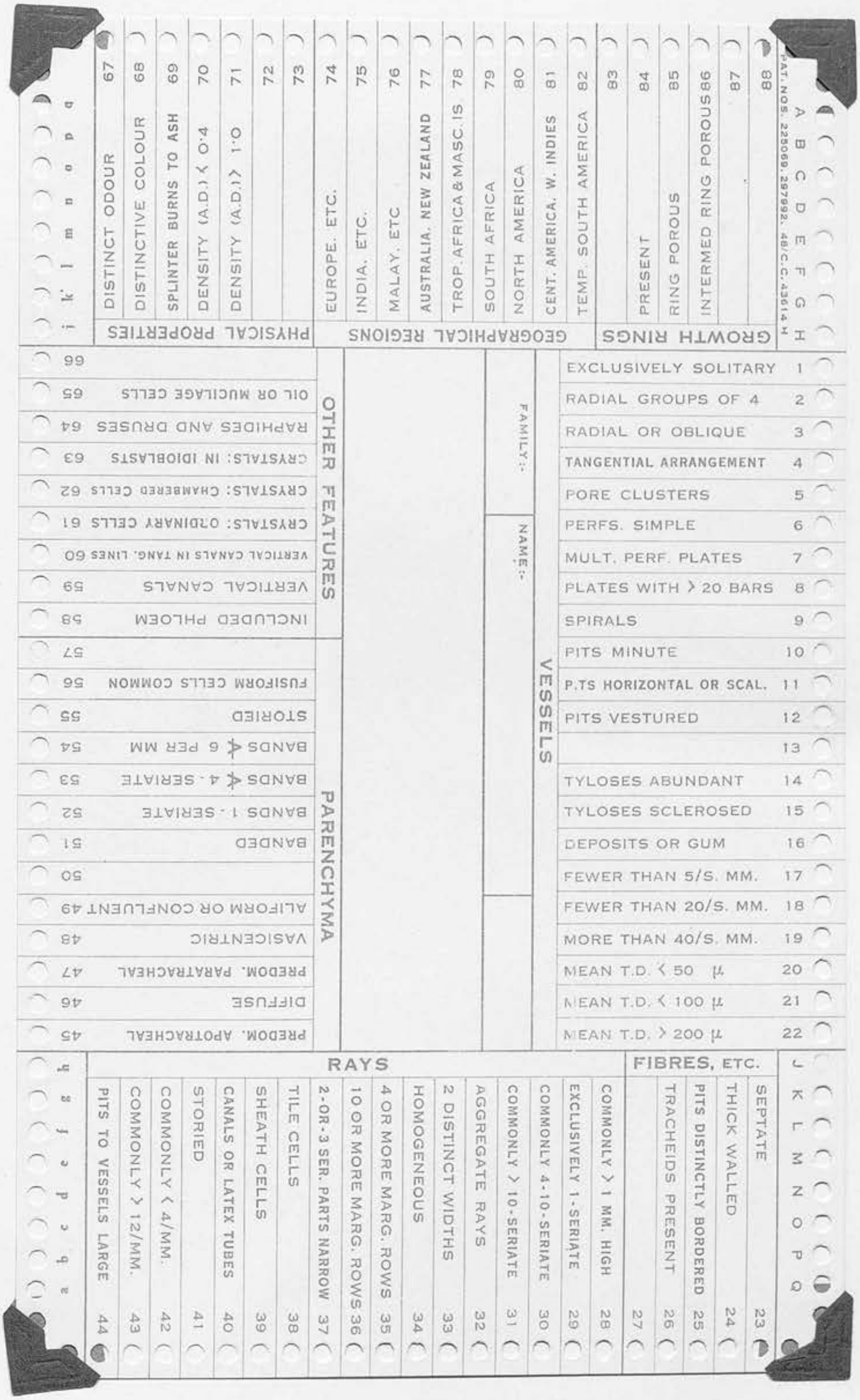
PLATE 26.

PLATE 27.



Anacardium occidentale.

PLATE 28.



PHYSICAL PROPERTIES
67 DISTINCT ODOUR
68 DISTINCTIVE COLOUR
69 SPLINTER BURNS TO ASH
70 DENSITY (A.D.) < 0·4
71 DENSITY (A.D.) > 1·0
72
73
GEOGRAPHICAL REGIONS
74 EUROPE. ETC.
75 INDIA. ETC.
76 MALAY. ETC
77 AUSTRALIA. NEW ZEALAND
78 TROP. AFRICA & MASC. IS.
79 SOUTH AFRICA
80 NORTH AMERICA
81 CENT. AMERICA. W. INDIES
82 TEMP. SOUTH AMERICA
GROWTH RINGS
83
84 PRESENT
85 RING POROUS
86 INTERMED RING POROUS
87
88
PAT. NOS. 225069. 297992. 48/C.C. 43614
A B C D E F G H
VESSELS
EXCLUSIVELY SOLITARY 1
RADIAL GROUPS OF 4 2
RADIAL OR OBLIQUE 3
TANGENTIAL ARRANGEMENT 4
PORE CLUSTERS 5
PERFS. SIMPLE 6
MULT. PERF. PLATES 7
PLATES WITH > 20 BARS 8
SPIRALS 9
PITS MINUTE 10
P.TS HORIZONTAL OR SCAL. 11
PITS VESTURED 12
13
TYLOSES ABUNDANT 14
TYLOSES SCLEROSED 15
DEPOSITS OR GUM 16
FEWER THAN 5/S. MM. 17
FEWER THAN 20/S. MM. 18
MORE THAN 40/S. MM. 19
MEAN T.D. < 50 μ 20
MEAN T.D. < 100 μ 21
MEAN T.D. > 200 μ 22
FAMILY:-
NAME:-
OTHER FEATURES
66
OIL OR MUCILAGE CELLS 65
RAPHIDES AND DRUSES 64
CRYSTALS: IN IDIOBLASTS 63
CRYSTALS: CHAMBERED CELLS 62
CRYSTALS: ORDINARY CELLS 61
VERTICAL CANALS IN TANG. LINES 60
VERTICAL CANALS 59
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57
FUSIFORM CELLS COMMON 56
STORIED 55
BANDS > 6 PER MM 54
BANDS > 4-SERIATE 53
BANDS 1-SERIATE 52
BANDED 51
50
ALIFORM OR CONFLUENT 49
VASICENTRIC 48
PREDOM. PARATRACHEAL 47
DIFFUSE 46
PREDOM. APOTRACHEAL 45
FIBRES, ETC.
SEPTATE 23
THICK WALLED 24
PITS DISTINCTLY BORDERED 25
TRACHEIDS PRESENT 26
27
RAYS
COMMONLY > 1 MM. HIGH 28
EXCLUSIVELY 1-SERIATE 29
COMMONLY 4-10-SERIATE 30
COMMONLY > 10-SERIATE 31
AGGREGATE RAYS 32
2 DISTINCT WIDTHS 33
HOMOGENEOUS 34
4 OR MORE MARG. ROWS 35
10 OR MORE MARG. ROWS 36
2-OR-3 SER. PARTS NARROW 37
TILE CELLS 38
SHEATH CELLS 39
CANALS OR LATEX TUBES 40
STORIED 41
COMMONLY < 4/MM. 42
COMMONLY > 12/MM. 43
PITS TO VESSELS LARGE 44
J K L M N O P Q

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PART II.

INTRODUCTION.

The problem of anatomical variation of the elements in the secondary wood of a tree trunk from the centre to the periphery has long been a subject of study. Brown, Panshin and Forsaith (3) sum up the situation in these words. "Most investigators have concerned themselves largely with textural variations and, to much lesser degree, with fluctuations, at different heights in the tree, in the percentage of the volume occupied by cells of a given type. Specific information dealing with the variation in the shape, structure, and arrangement of the several xylary elements at different places, horizontally and vertically, in a tree is very meagre".

It is widely accepted that the structure of the secondary wood elements in the centre of the tree may differ in size and configuration from those towards the outside. It is also believed that the structure of the wood elements would attain the specific characters of the tree at a certain stage and thereafter those characters would remain constant throughout the subsequent stages of growth. Such a stage where the characters become fixed I believe is generally referred to as the mature wood stage.

Consequently a study of the characters of the mature wood becomes necessary for anatomical identification and classification of timbers. De Bruyne (4) says that "in attempts to assess the diagnostical value of anatomical features selecting mature wood is imperative since the variations between the juvenile and adult stage within a species must not interfere with the variations between the adult stages of the congeners".

The problem then is how to locate the mature wood portion of the tree trunk. In some trees growth rings are absent or since growth is a continuous process throughout the year they become so indefinite that they could not be counted to calculate the age of a tree.

According to Metcalfe and Chalk (5) "owing to changes in cell dimensions that occur from the pith outwards at any given level, specimens should be located at some distance from the pith; a suitable position is often at the edge of the heartwood in the specimen including both heartwood and sapwood". Here again in certain softwoods it is not possible to distinguish the heartwood and sapwood even with the help of a lens. In such cases evidently specimens should be located at "some distance from the pith".

This part of the investigation deals with a very thorough and exhaustive study of the wood elements of the secondary wood from the centre to the periphery. The data evolved from the work would satisfy to some extent two important purposes.

(1) It provides specific information dealing with variation in the shape structure and arrangements of the wood elements at different levels and at different portions of the same level.

(11) It gives information regarding the selection of a sample from the secondary wood region at different distances away from the pith.

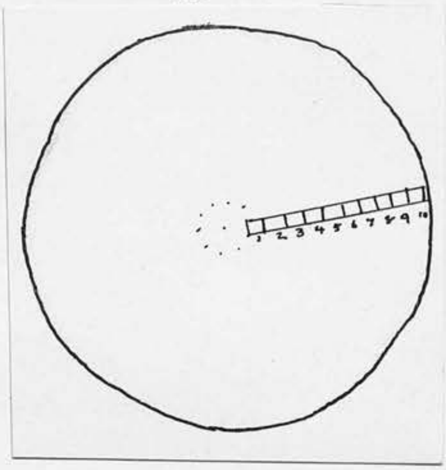
<u>Material and Method.</u>

The material for this study was carefully selected from living trees as already described. Rendle (6) has stated "that several closely related species of a large and widely distributed genus are identical so far as their wood structure is concerned". I have therefore selected different species of trees belonging to different genera and families for the investigation. In these trees growth rings are not conspicuous and in some of them the heartwood and sapwood are not to be differentiated by the naked eye or hand lens.

Blocks of wood $1\frac{1}{2}$ cm x 1 cm x 1 cm were cut for sectioning from the same radius of the lower and upper discs of the five species described in Part I. A series of blocks were cut from the centre to the periphery and labelled as indicated in the figure A.

Thus Block No. 1 is the innermost block just at the beginning of the secondary wood and the rest are numbered in order of their position towards the outside.

Fig. A.



Sections from each block are taken in the usual way and a portion of each block macerated separately for intensive study of the individual elements. Observations were made in the following characters.

(1) The number of vessels present in 2 sq.mm.

(2) The diameter of the vessels in μ

(3) Length of the vessel members in μ

(4) Height of the fibre in μ

(5) Height of the ray in μ

(6) Width of the ray in μ

The vessels were observed in an area of 2 sq.mm., - the number of vessels and the radial diameter of each vessel in this area were accurately counted and measured under the microscope. To obtain a fair average an area of 2 sq.mm., was noted at nine different places in the same cross section of every block.

To find out the percentage of large vessels present in the various blocks, a convenient size of the vessel which is commonly occurring in all the blocks, is chosen. Thus in each tree a different size is taken as a standard.

From the macerated tissue from each block the total length of the vessel member and length of the fibre were measured from 24 different samples.

To find out the height and width of the ray tangential sections of every block was examined and 24 samples of rays from the different portions of the same section were measured.

The results obtained from each block were tabulated.

VESSELS - Variations in their distribution, diameter and total member length.

Observations.

The data collected from the observations on the vessel distribution, diameter and total length of the vessel members shows the details of the structural variation that take place in the vessels of the secondary wood of some dicotyledonous trees from the centre to the periphery.

I The mean number of vessels per 2 sq:mm., and the range of variation in each block of the lower and upper regions of the trees are recorded in the following five Tables (~~all dimensions in~~) and graphically represented in Figs. 1 - 5.

TABLE 1

Pajanelia rheedii

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	7	16.25	35	I	19	30.9	43
II	5	8	12	II	13	18.3	26
III	4	6.4	12	III	7	11.3	16
IV	4	8.7	16				
V	5	8.2	12				

FIG. 1

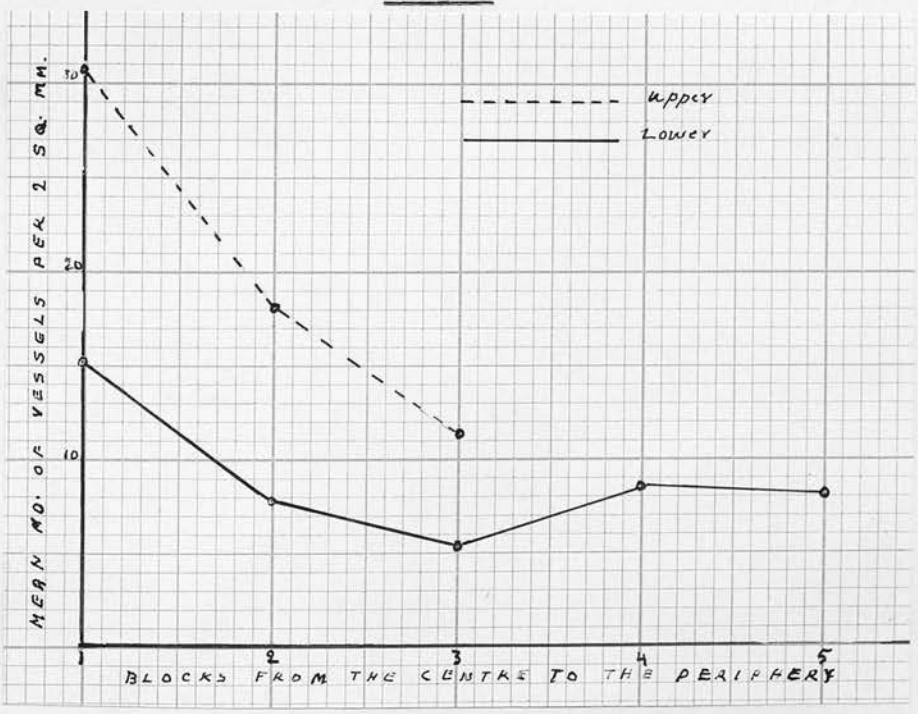


TABLE 2

Macaranga peltata

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	5	9.6	14	I	12	19	47
II	10	11.3	14	II	9	12.8	15
III	6	10	19	III	8	10.9	17
IV	6	10.8	24	IV	6	9.8	16
V	10	12	18	V	7	11	22

FIG. 2

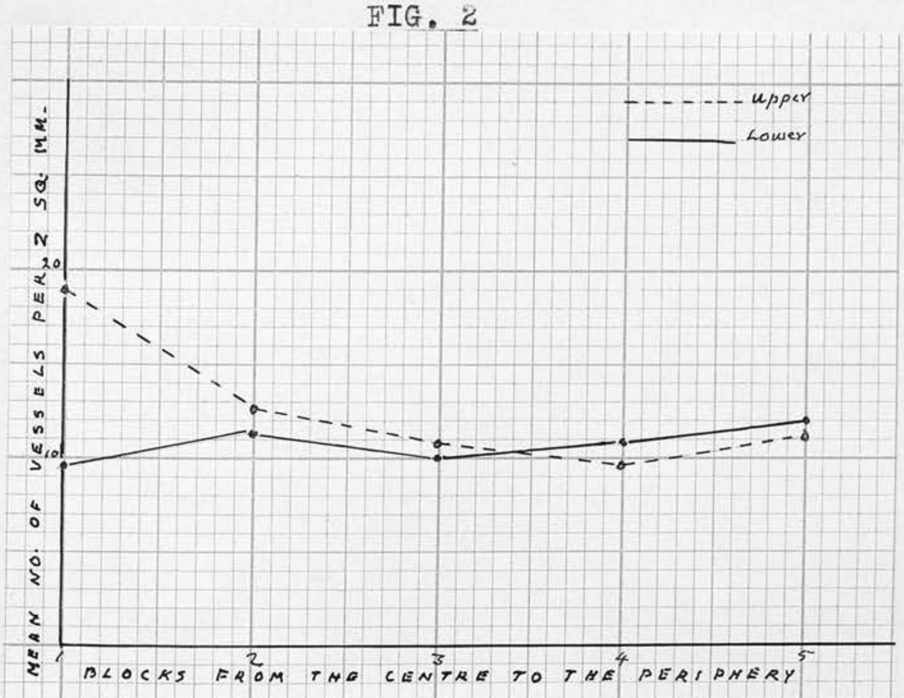


TABLE 3

Erythrina stricta.

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	2	4.6	9	I	2	4.9	11
II	1	3.3	6	II	3	5.2	8
III	1	3.3	5	III	1	4.3	8
IV	1	4.7	12	IV	1	4.3	7
V	1	2.9	5				
VI	1	4.6	12				

FIG. 3

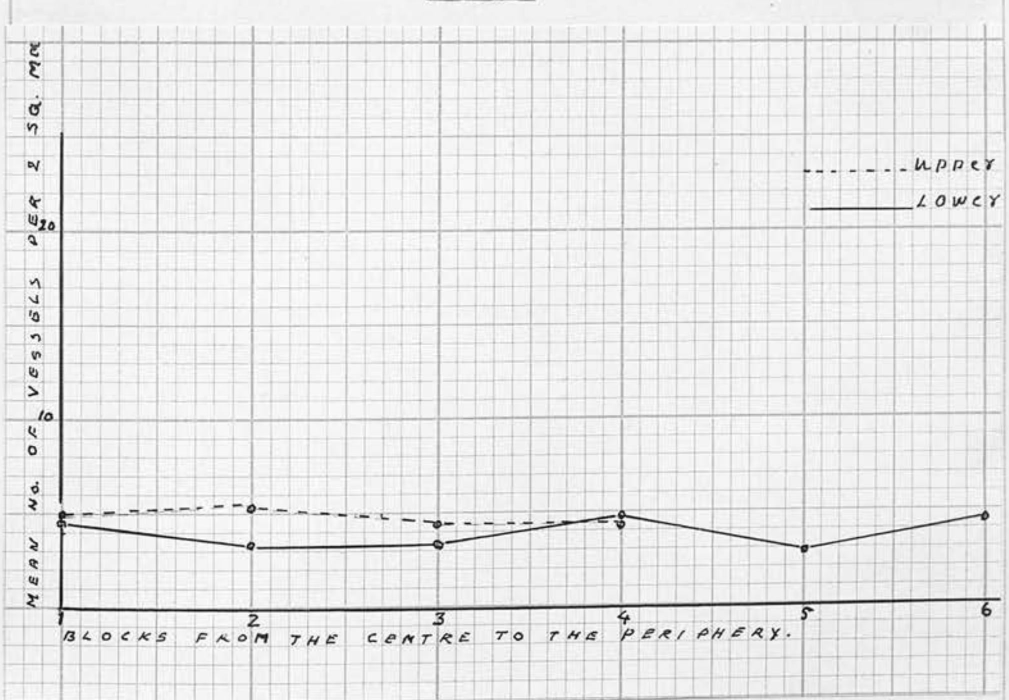


TABLE 4

Tabernaemontana dichotoma

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	89	115.8	141	I	90	119.8	144
II	74	100.3	115	II	91	104.7	123
III	78	81.7	89	III	77	88.8	106
IV	72	79.9	91	IV	85	104.7	187
V	66	80.3	91		—		

FIG. 4

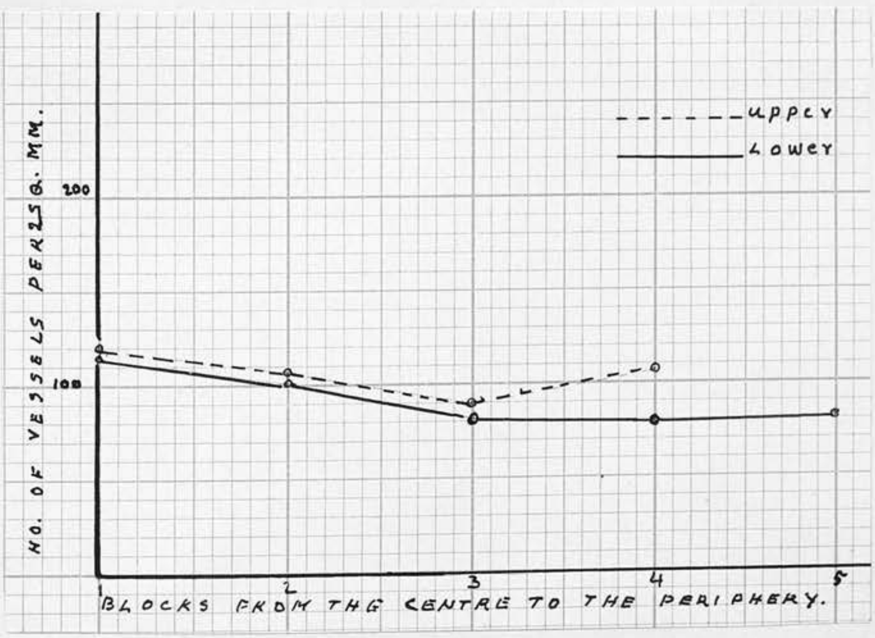
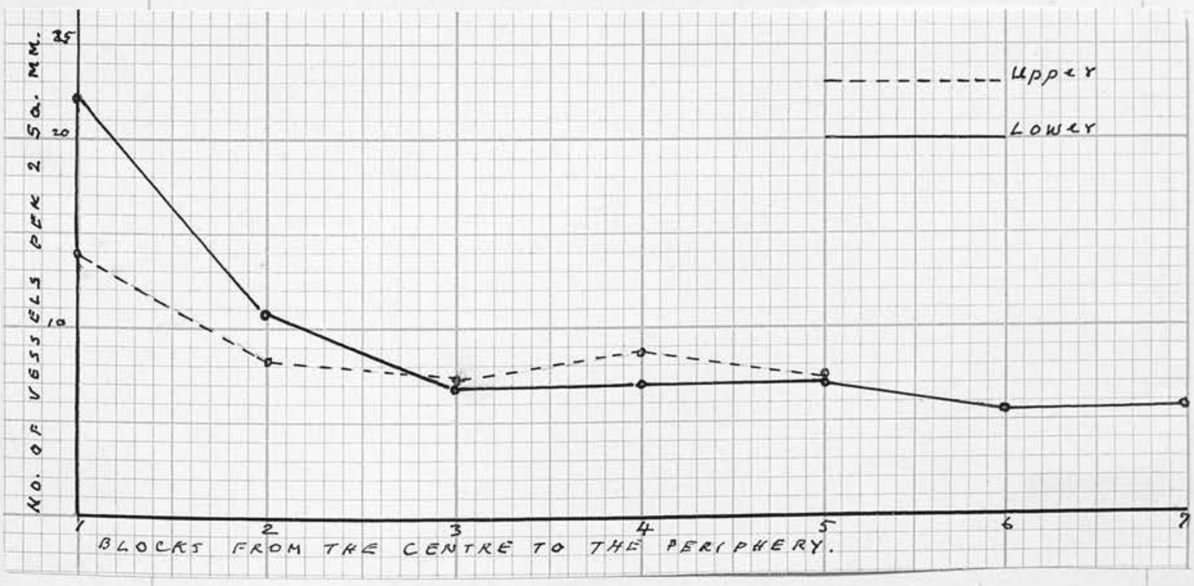


TABLE 5

Anacardium occidentale

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	8	22.0	59	I	11	13.8	18
II	6	10.7	14	II	5	8.1	14
III	6	6.9	8	III	5	7.3	10
IV	5	6.9	10	IV	5	8.7	13
V	6	7.1	8	V	3	7.2	12
VI	4	5.6	6				
VII	3	5.8	13				

FIG. 5



From the tables it is clear that there is a tendency to reduction in the number of vessels per unit area towards the outside from the centre of the tree trunk. Block No. I, the innermost block in all the trees shows a greater number of vessels than any other block of the same level excepting in the basal region of M. peltata. The decrease however is not gradual. The figures 1 - 5 show the distribution curve. It is clear from the tables and the graph that in some cases there is a substantial difference only between the outermost and innermost block regarding this character.

Thus in P. rheedii at the base, a decrease in the number of vessels by 50% is noted in the outermost block from the innermost one. In A. occidentale the decrease is by 73% at the base; in T. dichotoma the decrease is by 31% at the base; in E. stricta and M. peltata there is no decrease. Those trees in which the vessels show a decrease towards the outside from the centre, also show that there is no great difference in this respect between the outer blocks of the same radius though they do not show a constant number of vessels per unit area. On the other hand the upper region of the trunk shows a remarkable decrease in the number of vessels per 2 sq:mm., towards the outside in all the five species. But here also the outer blocks do not show great differences. In many cases the distribution curve is found to be irregular. This can be explained. It is observed in these materials that though the growth rings are not conspicuous under the lens they are seen under the microscope as already described. The vessel elements in the inner regions of the ring are found to be arranged closely and are greater in number per unit area. Blocks which have such portions of growth rings show a greater number of vessels per unit area than the other blocks. Thus in some cases the distribution curve and the tables do not show a steady decrease in the number of vessels per 2 sq:mm., towards the outside.

II A change in the mean diameter of the vessels was evident from the centre to the periphery. In both the lower and upper regions of the tree trunk the mean radial diameter shows an increase towards the outside. In some it is a steady increase. Tables 6 - 10 show the results obtained from the measurements made, (all measurements in μ) and figures 6 - 10 show the graph representing the changes in the radial diameter from the centre to the periphery.

TABLE 6

Pajanelia rheedii

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	44	143.9	254	I	22	107	222
II	67	201	300	II	33	167	277
III	78	192	333	III	33	186	489
IV	56	198	367				
V	67	209	356				

FIG. 6

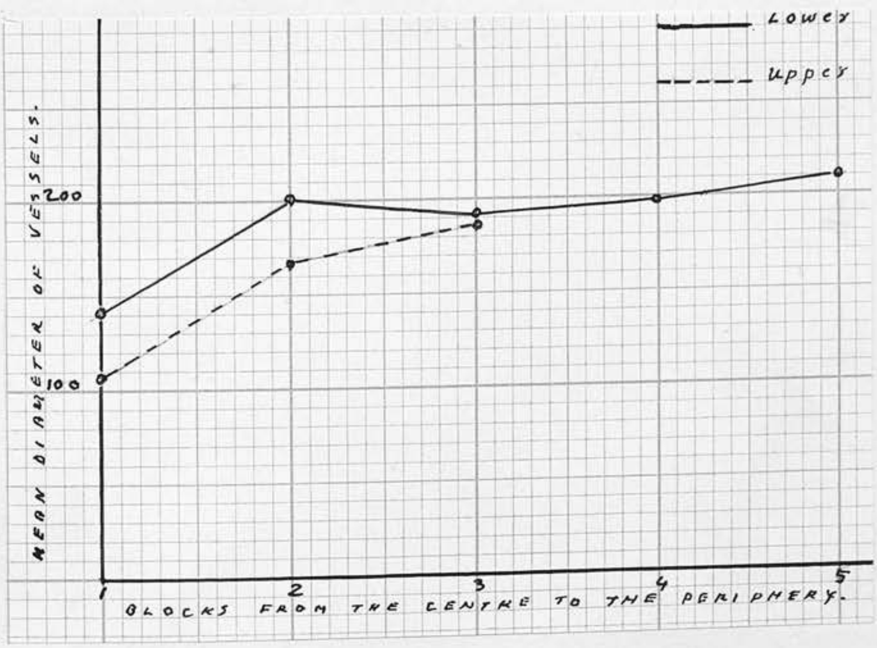


TABLE 7

Macaranga peltata

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	22	175	244	I	44	134	222
II	56	174	278	II	56	182	278
III	33	177	278	III	67	209	278
IV	56	204	300	IV	56	211	222
V	44	200	311	V	56	218	911

FIG. 7

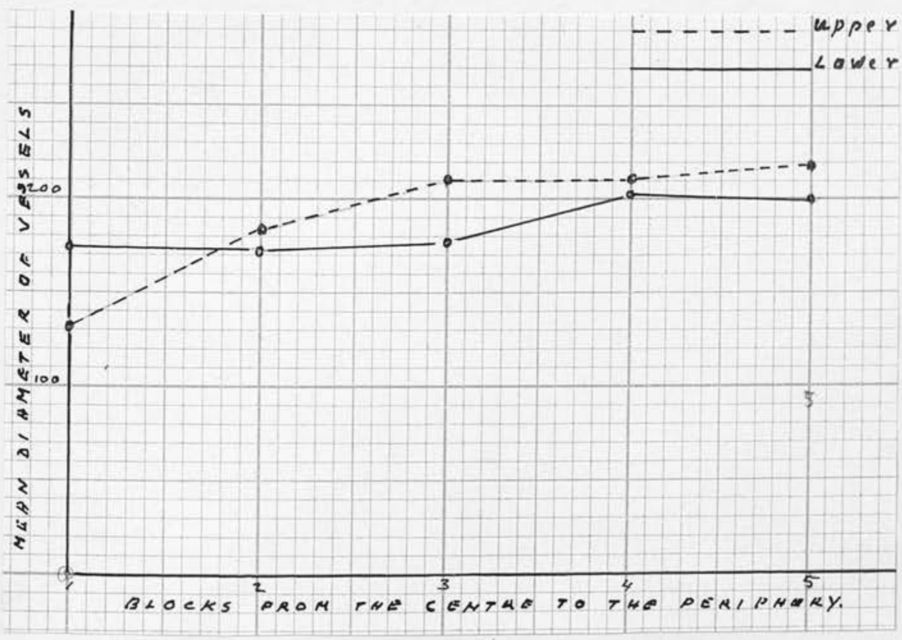


TABLE 8

Erythrina stricta

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	56	253	378	I	78	206	311
II	111	258	400	II	111	233	400
III	99	284	411	III	111	256	389
IV	45	263	478	IV	133	277	335
V	111	281	422				
VI	56	280	444				

FIG. 8

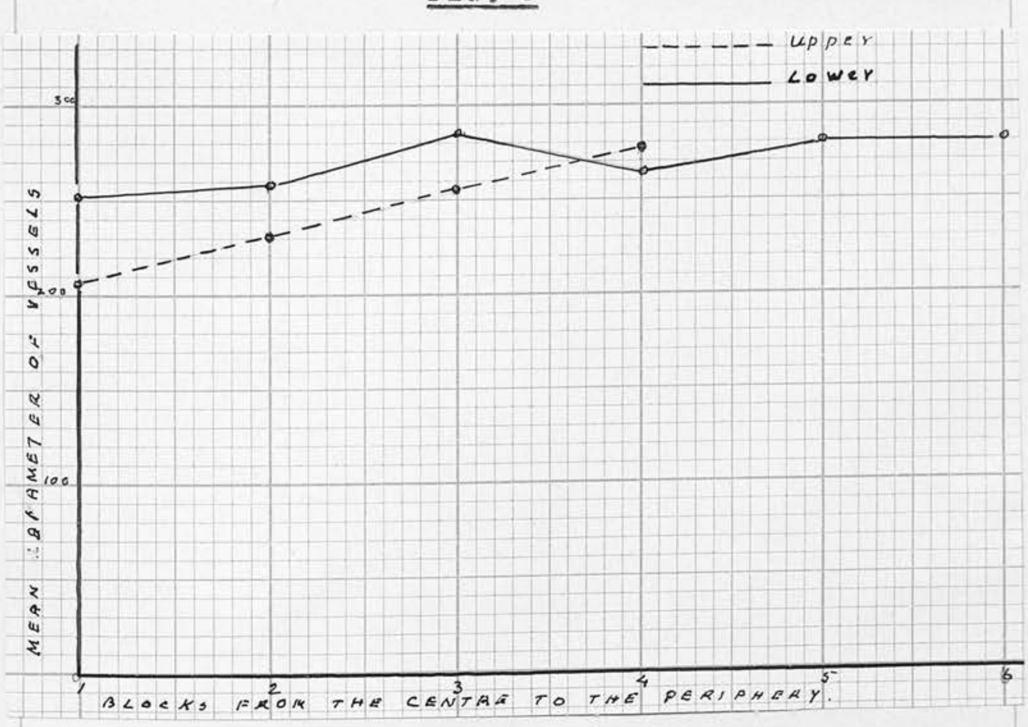


TABLE 9

Tabernaemontana dichotoma

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	33	65	100	I	22	58	78
II	33	67	100	II	56	72	111
III	56	81	111	III	56	79	111
IV	67	91	111	IV	56	87	111
V	67	85	111				

FIG. 9

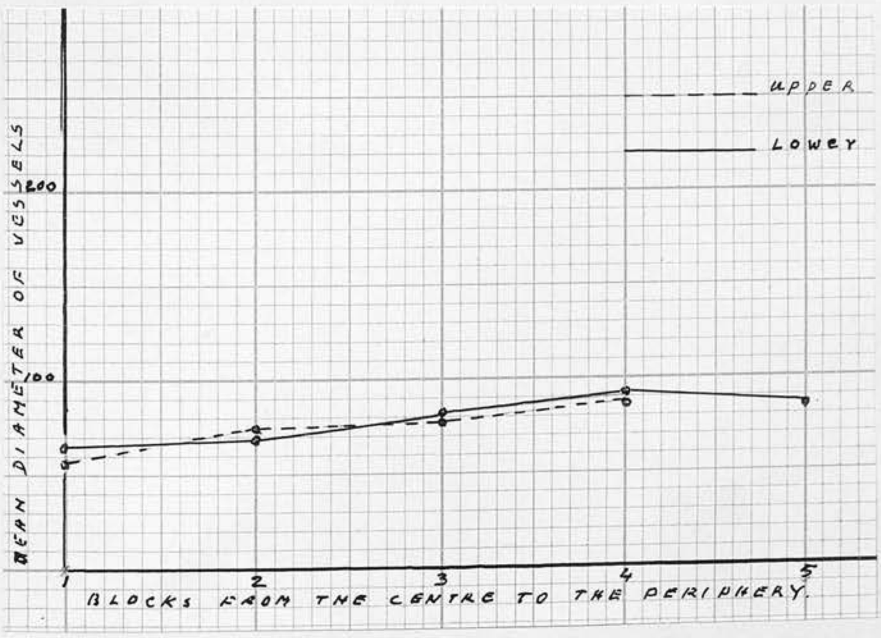
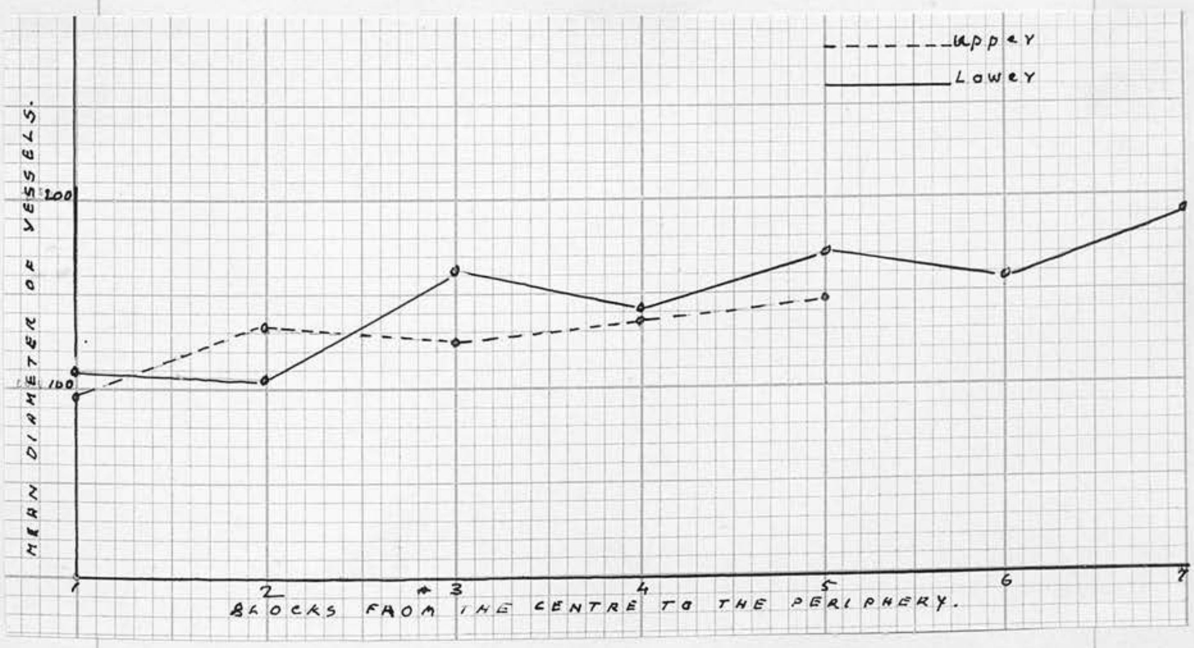


TABLE 10

Anacardium occidentale.

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	22	109	178	I	44	99	189
II	22	106	178	II	44	133	200
III	56	163	200	III	56	125	189
IV	44	142	222	IV	56	136	222
V	56	172	222	V	22	147	233
VI	111	157	233				
VII	73	192	333				

FIG. 10



The plates 1 - 15 illustrate the size of the vessels in the inner block, middle block and the outermost block in the various trees. These plates show the largest vessel in the respective blocks. It is clear from these observations that there is a general increase in the mean diameter of the vessels towards the periphery.

III The occurrence of large vessels in the various regions are shown in the following Tables and represented graphically in Figs. 11 - 15.

TABLE 11

Pajanelia rheedii

Lower				Upper			
Block	Total No. of vessels measured	No. above 150 μ	Percentage of large vessels	Block	Total No. of vessels measured	No. above 150 μ	Percentage of large vessels
I	130	57	44.3	I	278	71	25.5
II	72	55	76.4	II	165	106	64.3
III	58	48	82.8	III	102	74	72.5
IV	78	63	83.3				
V	74	61	82.4				

FIG. 11

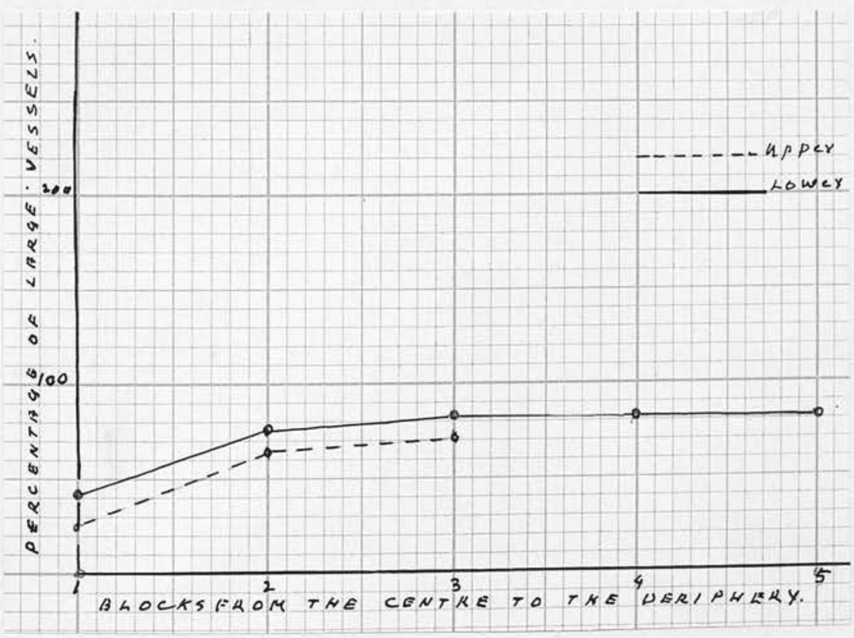


TABLE 12

Macaranga peltata

Lower				Upper			
Block	Total No. of vessels measured	No. above 200 μ	Percentage of large vessels	Block	Total No. of vessels measured	No. above 200 μ	Percentage of large vessels
I	86	32	37.2	I	191	6	3
II	102	34	33.3	II	115	46	40
III	90	32	35.5	III	98	61	62
IV	97	48	49.4	IV	88	56	63
V	112	60	53.5	V	107	61	57

FIG.12

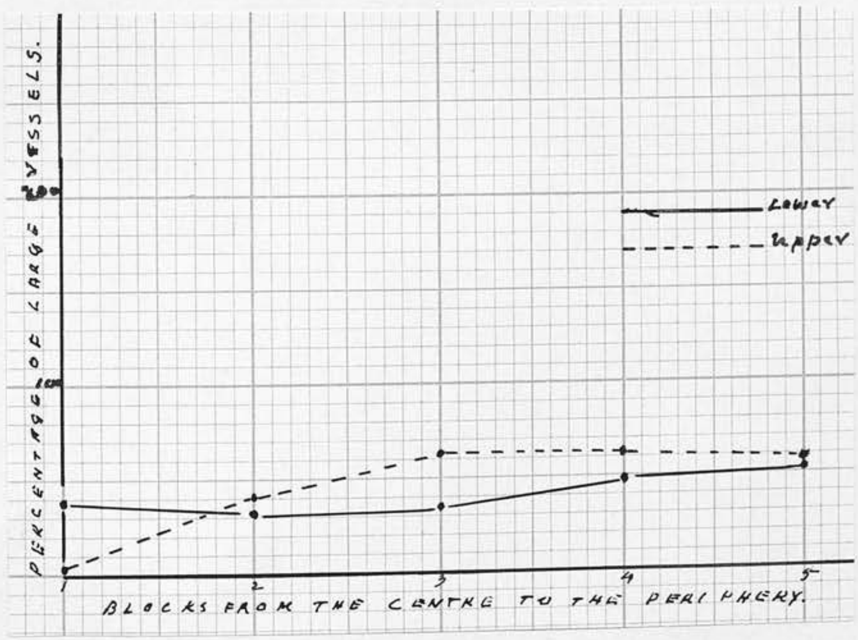


TABLE 13

Erythrina stricta

Lower				Upper			
Block	Total No. of vessels measured	No. above 300μ	Percentage of large vessels	Block	Total No. of vessels measured	No. above 300μ	Percentage of large vessels
I	41	9	22	I	44	4	9.1
II	31	8	21.3	II	47	5	10.6
III	30	10	33.3	III	39	7	18
IV	42	10	23.8	IV	39	18	46
V	26	8	30.7				
VI	41	14	34				

FIG.13

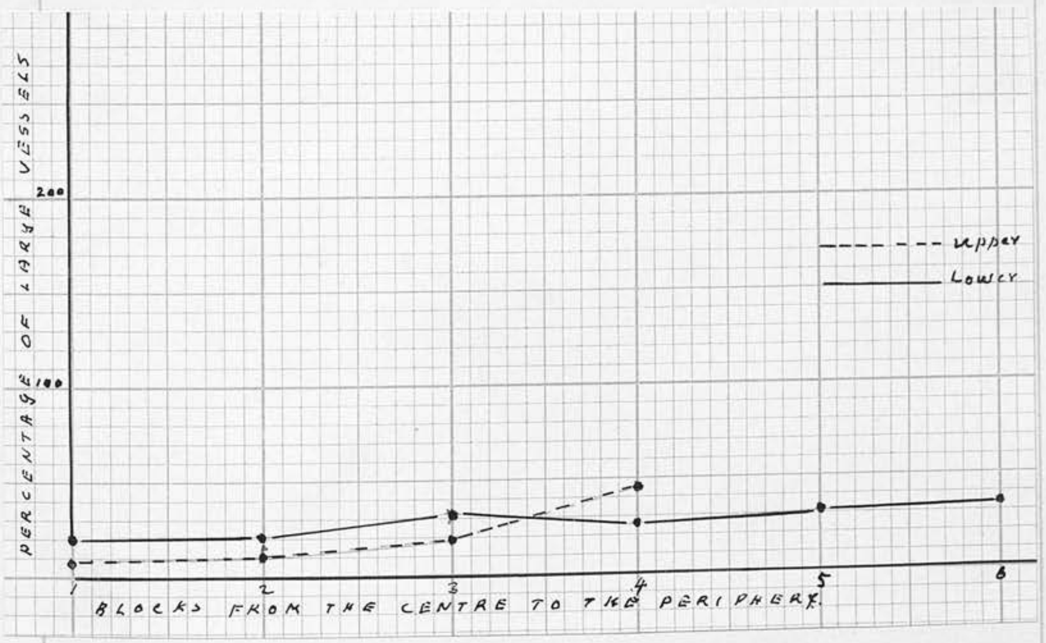


TABLE 14.

Tabernaemontana dichotoma

Lower				Upper			
Block	Total No. of vessels measured	No. above 80μ	Percentage of large vessels	Block	Total No. of vessels measured.	No. above 80μ	Percentage of large vessels
I	126	9	7	I	117	0	0
II	126	9	7	II	117	24	20.5
III	117	40	34	III	117	51	43.5
IV	117	40	75	IV	125	72	57.6
V	117	69	59				

FIG. 14.

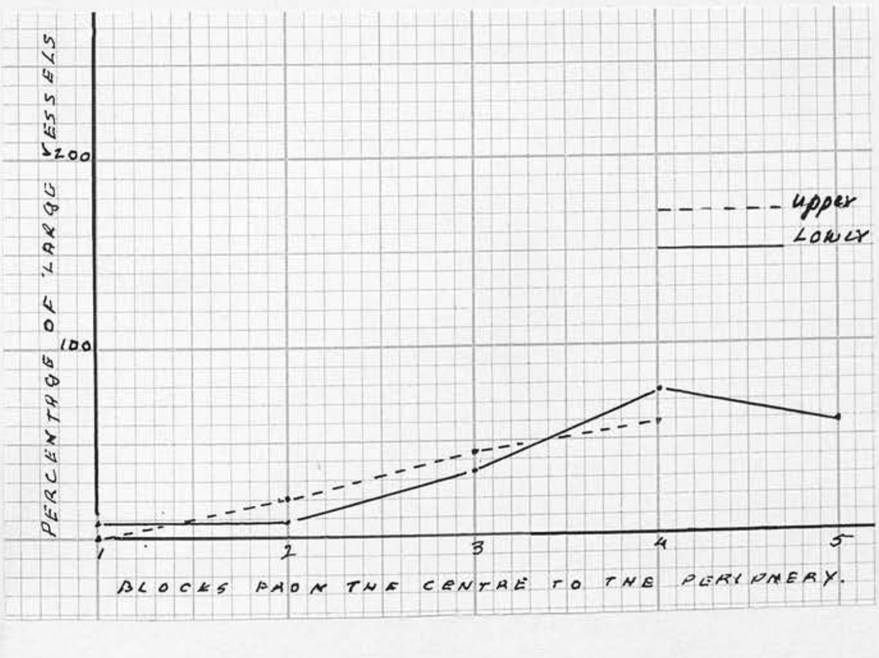
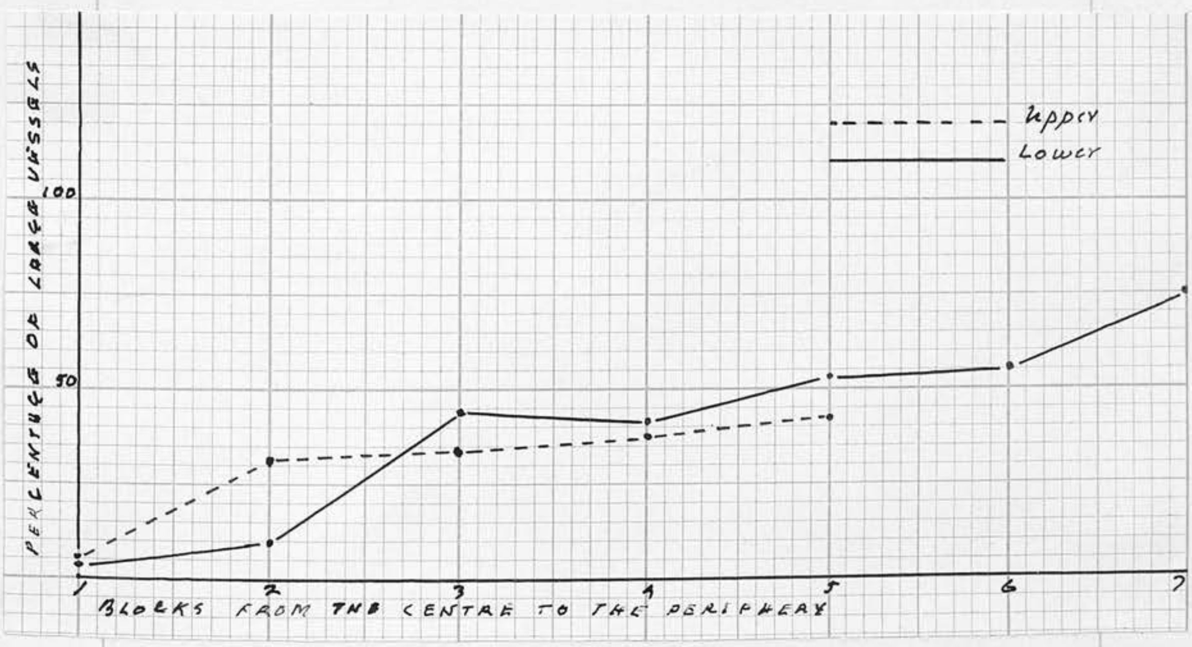


TABLE 15.

Anacardium occidentale

Lower				Upper			
Block	Total No. of vessels mea-sured	No. above 150µ	Per-centage of large vessels	Block	Total No. of vessels mea-sured	No. above 150µ	Per-centage of large vessels
I	198	8	4	I	124	6	5
II	96	9	9.4	II	73	23	31.5
III	62	30	48.4	III	66	22	33.3
IV	62	26	42	IV	78	29	37
V	64	34	53	V	65	27	41.5
VI	60	33	55				
VII	52	39	75				

FIG. 15.



Tables 11 - 15 give an idea of the percentage of large vessels (i.e. those vessels reaching the probable maximum size for the species) that occur in the various regions of the same level. The graphs 11 - 15 show that the increase in the percentage of the large vessels is gradual towards the outside. Thus the increase in the mean diameter of vessels per unit area from the centre to the outside is mainly due to the increase in the number of larger vessels formed in the outer regions towards the periphery. It is also partially due to the increase in the size of the individual vessels. This increase of the size does not continue indefinitely. There is also no absolute stability regarding the radial diameter, yet it has never gone beyond certain dimensions in each species and the vessels of the maximum diameter occurs in different percentage in the different outer regions of the same level. Hence the mean radial diameter also varies in different portions of the same level in the secondary wood.

IV There were no clear line of changes in the total length of the vessel members in the various blocks of both lower and upper portions of the tree trunk. The Tables 16 - 20 give the results of the measurements made (all measurements in μ) on the vessel members from a maceration of the various blocks. Figs. 16 - 20 present the graphs showing the variations in vessel member length.

TABLE 16

Pajanelia rheedii

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	322	462	567	I	167	368	567
II	111	319	478	II	133	400	666
III	278	554	844	III	267	440	556
IV	322	408	611				
V	251	408	556				

FIG. 16

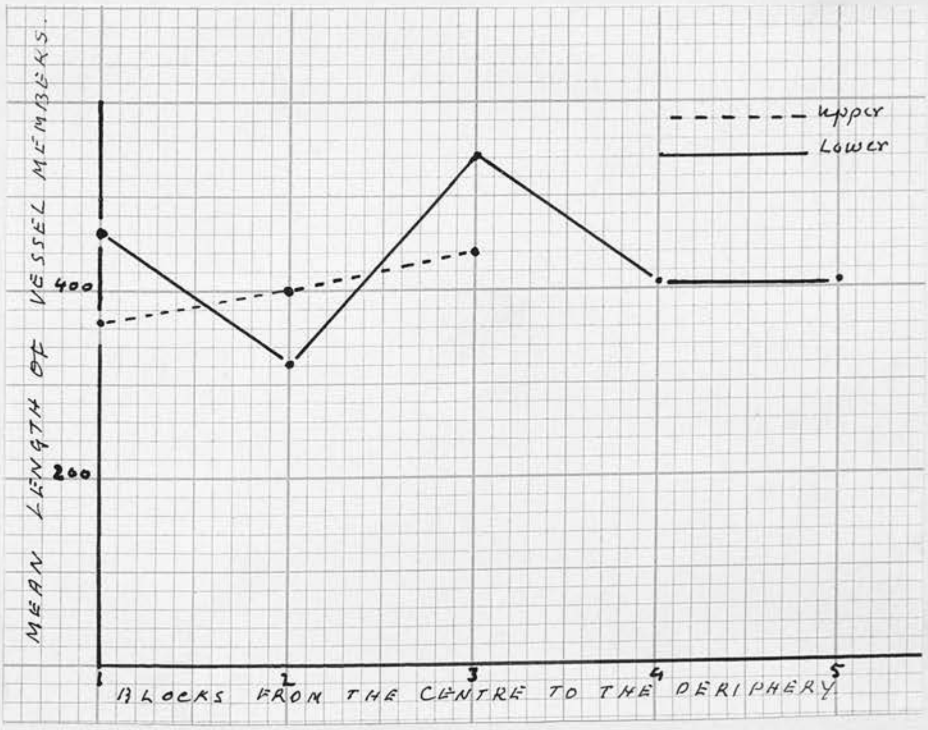


TABLE 17

Macaranga peltata

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	500	925	1233	I	556	710	1056
II	778	1032	1278	II	811	980	1333
III	311	935	1389	III	444	781	1111
IV	611	936	1155	IV	488	842	1100
V	600	955	1267	V	621	826	1111

FIG. 17

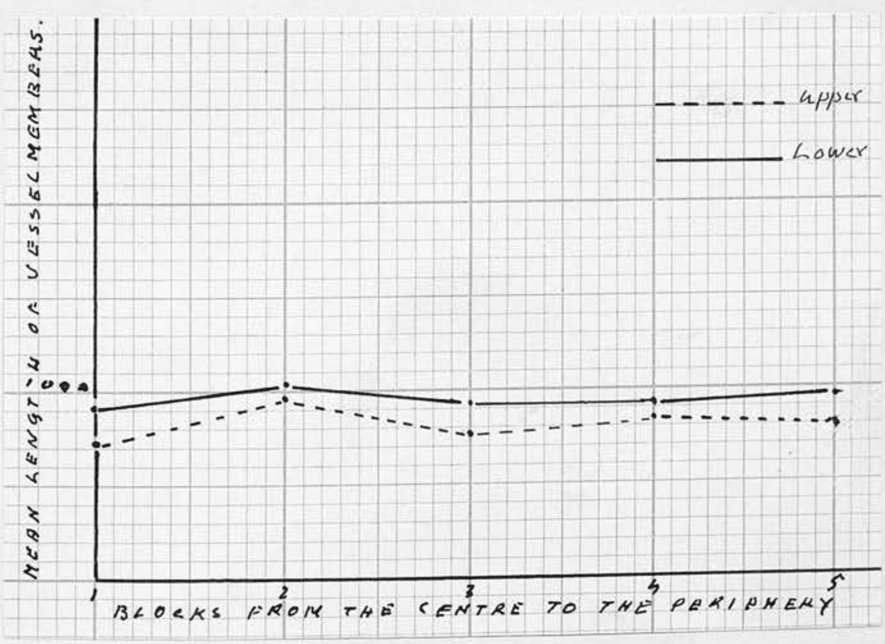


TABLE 18.

Erythrina stricta

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	111	272	333	I	222	261	311
II	222	308	444	II	200	248	333
III	111	265	444	III	167	252	355
IV	167	269	388	IV	167	229	278
V	111	281	422				
VI	189	280	467				

FIG. 18

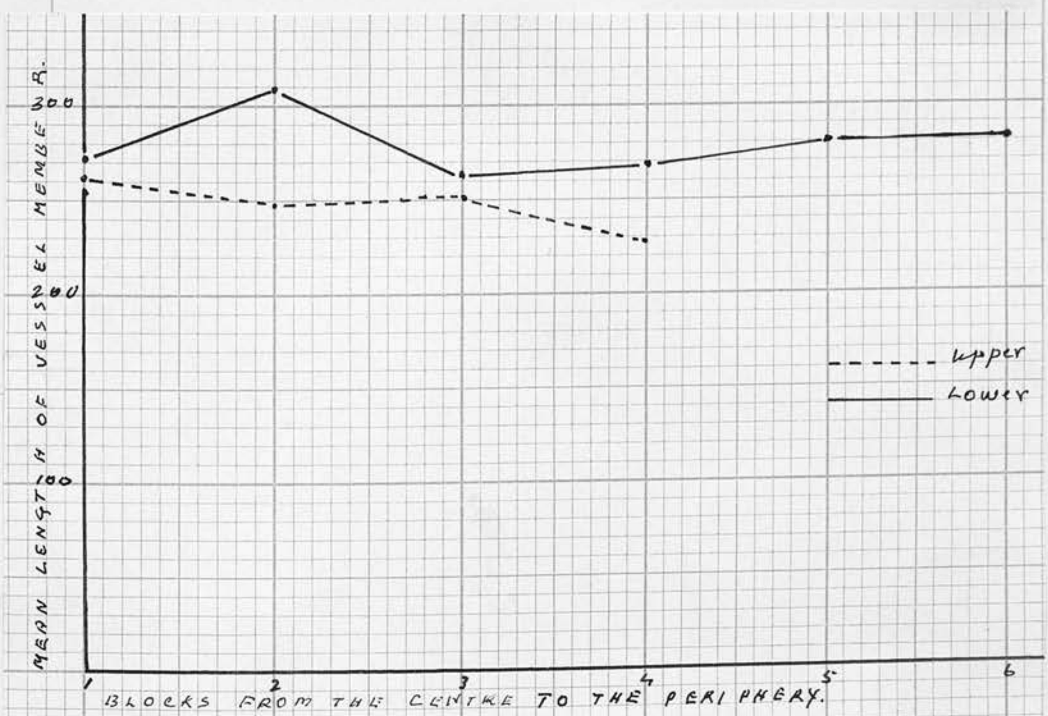


TABLE 19

Tabernaemontana dichotoma

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	666	848	1167	I	644	881	1111
II	533	848	1167	II	6111	894	1177
III	733	900	1144	III	556	898	1222
IV	667	941	1133	IV	567	803	900
V	644	885	1111				

FIG.19

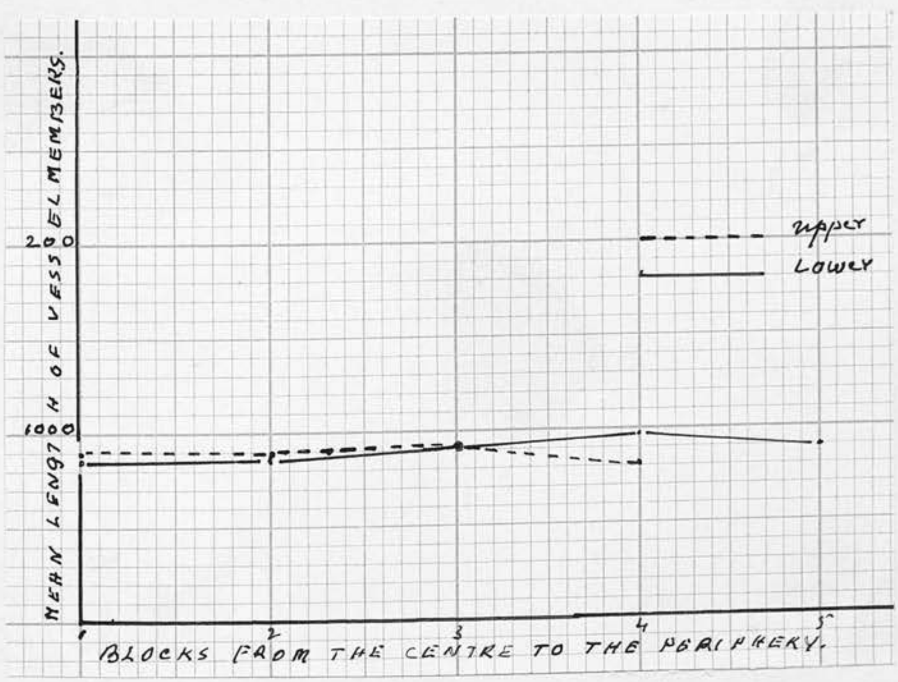
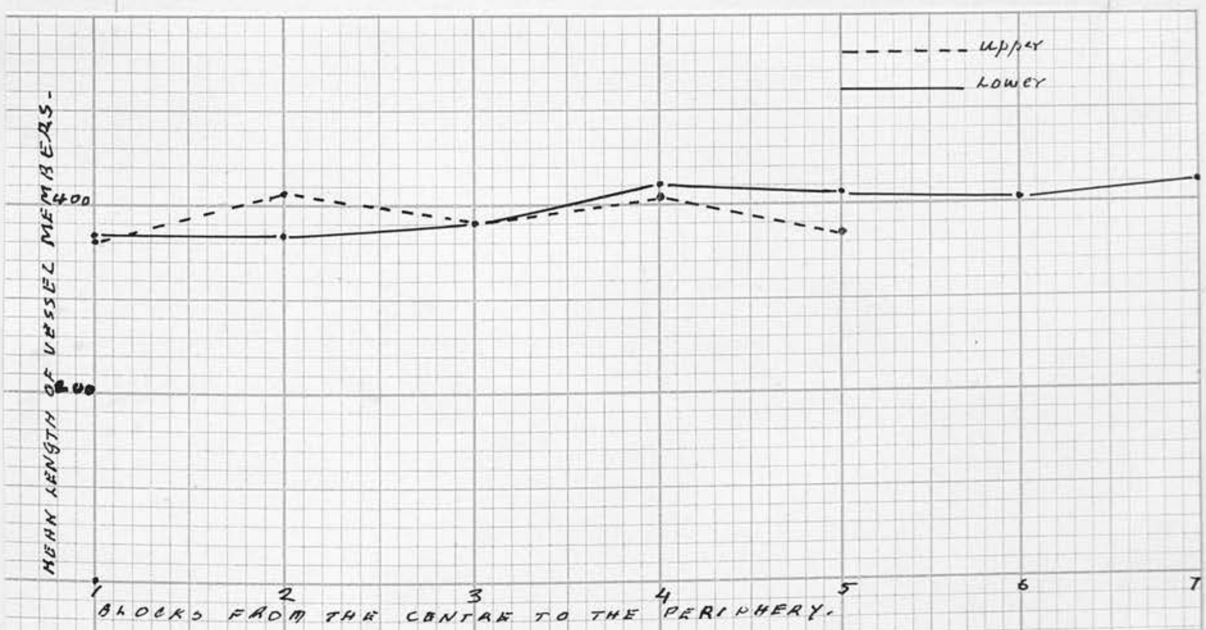


TABLE 20.

Anacardium occidentale

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	256	369	500	I	244	364	444
II	222	367	500	II	244	412	500
III	244	381	556	III	222	382	446
IV	~~189~~	422	556	IV	222	414	466
V	222	414	556	V	278	373	456
VI	311	408	644				
VII	278	420	567				

FIG. 20.



It is noted that in A. occidentale and M. peltata there is an increase in the total length of the vessel members from the centre to the outside in both lower and upper portions. The graph does not show however a smooth curve. In T. dichotoma and E. stricta the lower portions show an increase in the same line but the upper regions show a considerable decrease in the outermost blocks. P. rheedii shows a decrease in the lower disc and an increase in the upper disc.

Discussion

Metcalfe and Chalk (5) have stated that for identification the "vessel diameter is best recorded as a mean figure, though varying according to position in the tree and conditions of growth". The facts observed above clearly supports that view. It also makes it clear that the mean diameter of vessels in different portions of the secondary wood of the same level varies considerably.

The observations made in the vessel member length also support Metcalfe and Chalk (5) in their view "that the vessel member length in common with other cell dimensions varies considerably within any species and even in different parts of the same tree". Bailey and Tupper (1) have shown "that the first formed members are shorter than those developed later". Observations made above show that in two species, M. peltata and A. occidentale the same feature occurs both in the lower and upper regions of the tree trunk. It is also true regarding the upper regions of P. rheedii and the lower regions of E. stricta and T. dichotoma, but on the other hand the upper regions of E. stricta and T. dichotoma and the lower region of P. rheedii show that the early formed vessel members are longer than those developed later.

Summary

The mean number of vessels per unit area observed in five species of different genera and families varies at different levels and in different portions of the same level. There is a tendency towards reduction in the number of vessels per unit area from the centre of the tree to the periphery in some of the species. This reduction is not a gradual one. After a certain stage of growth no great changes in the distribution of vessels per unit area were noted in the newly formed wood. At the same time there was no constancy regarding the number of vessels formed.

The mean radial diameter of vessels shows a general increase when examined from the centre to the periphery. The increase in the mean diameter is mainly due to the increase in the number of larger vessels formed in the outer regions towards the periphery and also partially due to the increase in the size of the vessels. This increase in the size of the individual vessels does not continue

indefinitely. There is no absolute stability regarding the radial diameter of large vessels yet it has never gone beyond certain size in each species, and that maximum size occurs in different percentage in the different outer regions of the same level. Hence the mean radial diameter also varies in different portions of the same level in the secondary wood.

RAYS - An examination of their size and structure.

Observations

A detailed study of the rays in the materials under investigation show the following results which are recorded in Tables. Each table explains the observations made on a particular character of the ray in the various blocks from the centre to the periphery in different levels.

I Observations on the height of the ray in the various blocks are recorded in the following Tables (all dimensions are in μ) and graphically represented in Figs. 21 - 25.

TABLE 21.

Pajanelia rheedii

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	133	305.7	567	I	111	233	456
II	111	279	500	II	200	293.5	500
III	111	305	611	III	156	273	478
IV	178	393	689				
V	222	401	678				

FIG. 21.

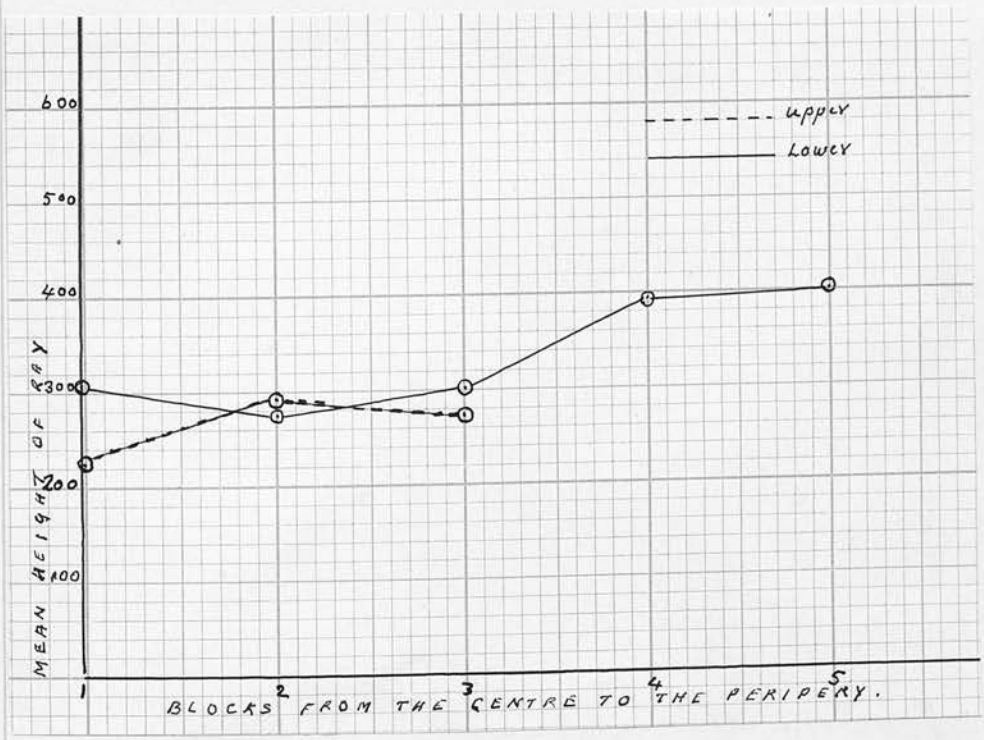


TABLE 22.

Macaranga peltata

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	556	1056	1611	I	444	885	1337
II	444	1231	2311	II	711	957	1499
III	556	1315	2778	III	444	897	1444
IV	600	1156	2000	IV	455	923	1444
V	256	1041	2444	V	233	966	1311

FIG. 22

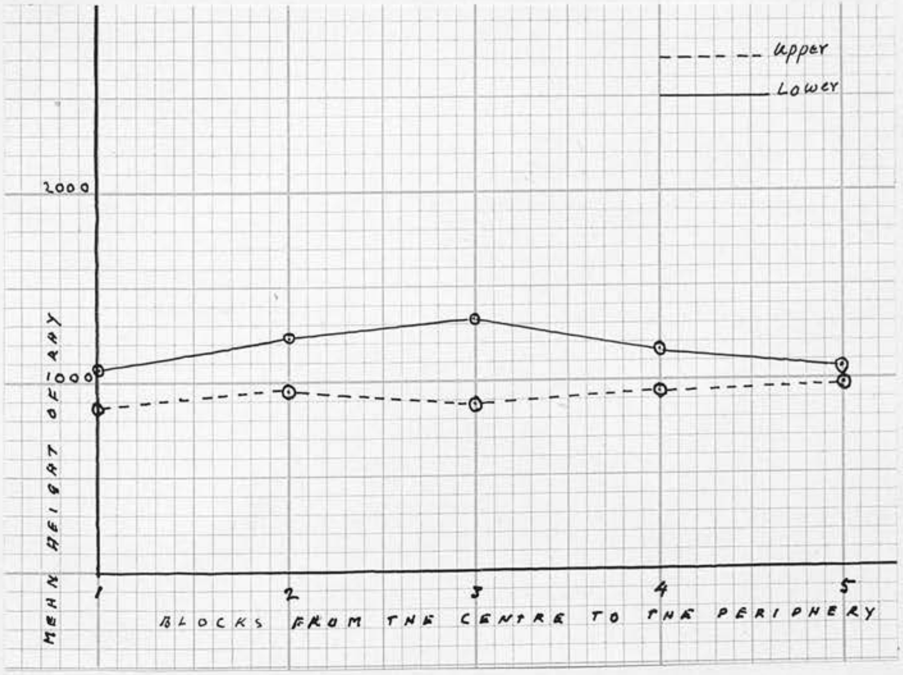


TABLE 23.

Erythrina stricta

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	778	1364	1844	I	777	1593	2444
II	611	1362	1988	II	777	1779	3000
III	591	1461	2222	III	577	1437	2166
IV	633	992	1770	IV	889	1345	2188
V	422	932	2044				
VI	399	1219	1833				

FIG. 23

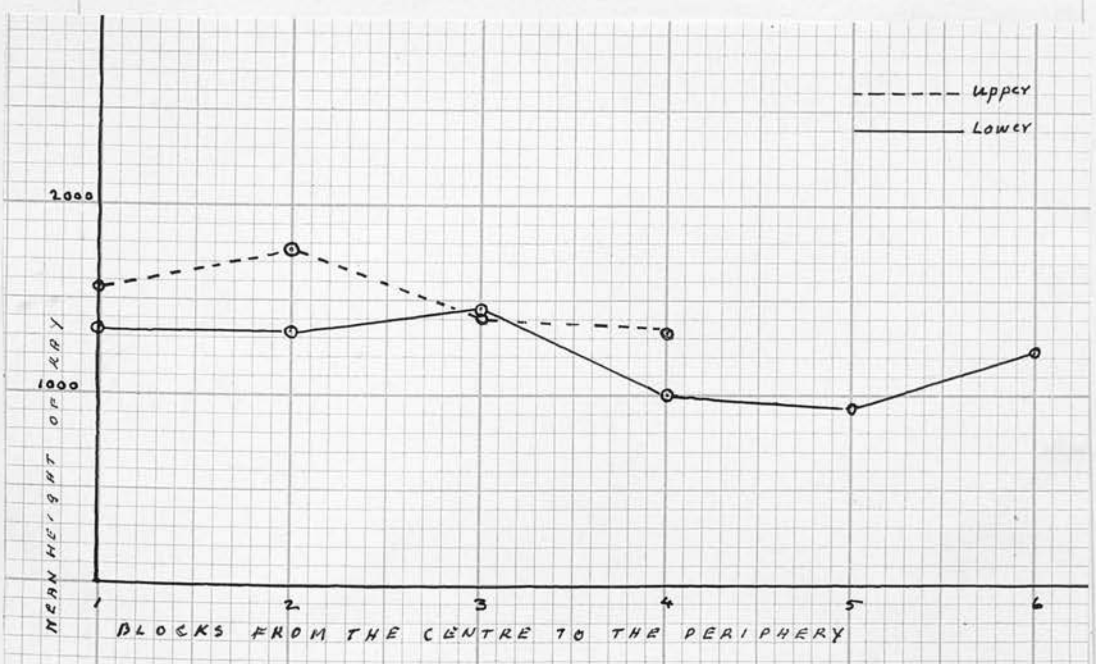


TABLE 24.

Tabernaemontana dichotoma

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	333	498	667	I	433	579	778
II	611	708	933	II	389	767	1167
III	500	664	778	III	333	539	1167
IV	389	553	889	IV	344	540	556
V	333	483	778				

FIG.24

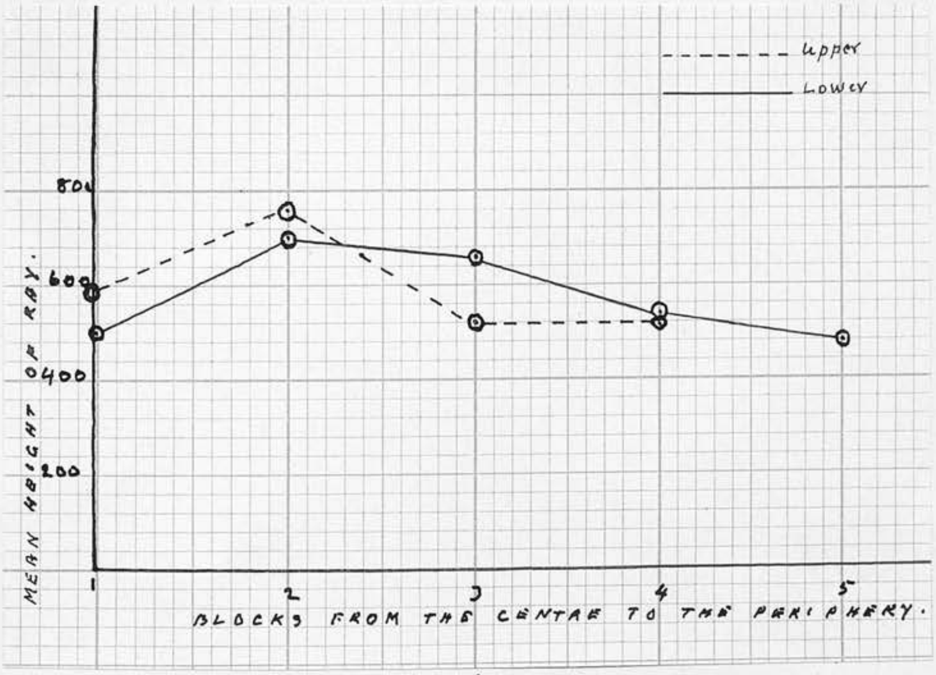
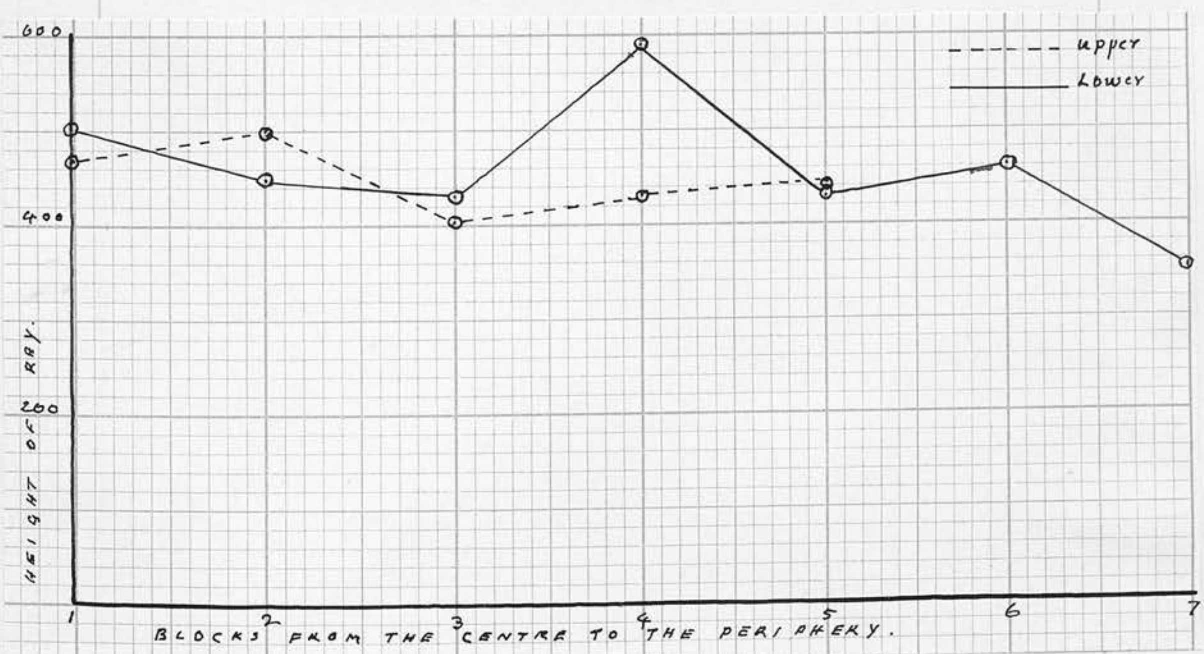


TABLE 25

Anacardium occidentale

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	156	504	889	I	333	475	922
II	222	452	711	II	289	499	667
III	288	427	678	III	256	405	867
IV	222	590	555	IV	256	429	867
V	244	426	677	V	278	430	733
VI	300	466	788				
VII	155	359	556				

FIG. 25



From the above tables it is clear that the mean height of the ray in the inner block is greater than that of the outer block in all the species except in <u>P. rheedii</u> and the upper portions of <u>M. peltata</u>. The reduction in the height towards the outside is not gradual and at the same time it does not take any definite course of change even in those trees where such a reduction is noted in the outer block. The decrease in such cases is not always very appreciable. Thus in <u>E. stricta</u> there is only a reduction by 10.7% at the lower region and 18.4% at the upper region; in <u>T. dichotoma</u> 8.27% at the lower region and 6.7% at the upper and in <u>A. occidentale</u> 27.7% at the lower region and 9.6% in the upper region.

It is noted that the height of the ray is very highly variable from place to place along the same radius and in different radii.

II Observations on the width of the ray in the various blocks are given in Tables below.

TABLE 26

Pajanelia rheedii

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	44	48	66	I	22	44	55
II	33	47	56	II	56	63	77
III	44	60	67	III	67	74	89
IV	55	58	67				
V	44	53	56				

FIG.26

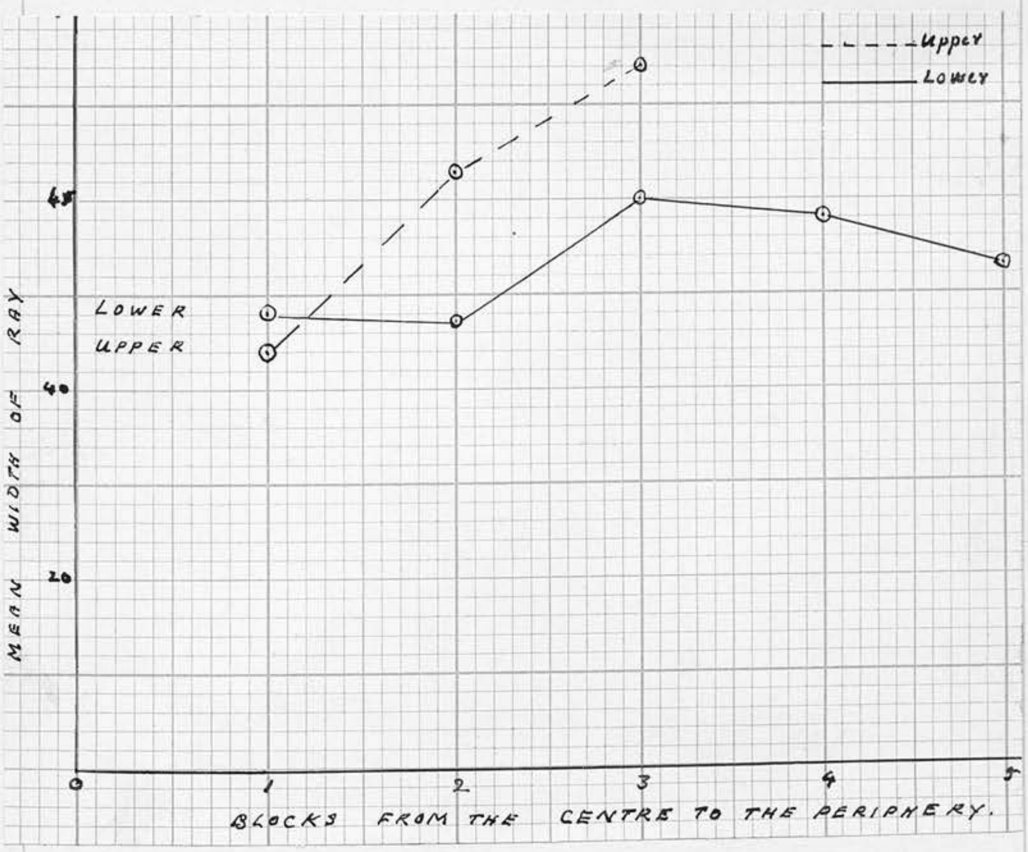


TABLE 27

Macaranga peltata

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	11	16	22	I	11	16	22
II	22	25	44	II	11	18	22
III	22	32	44	III	11	20	22
IV	22	32	33	IV	22	24	33
V	22	47	100	V	11	29	44

FIG. 27

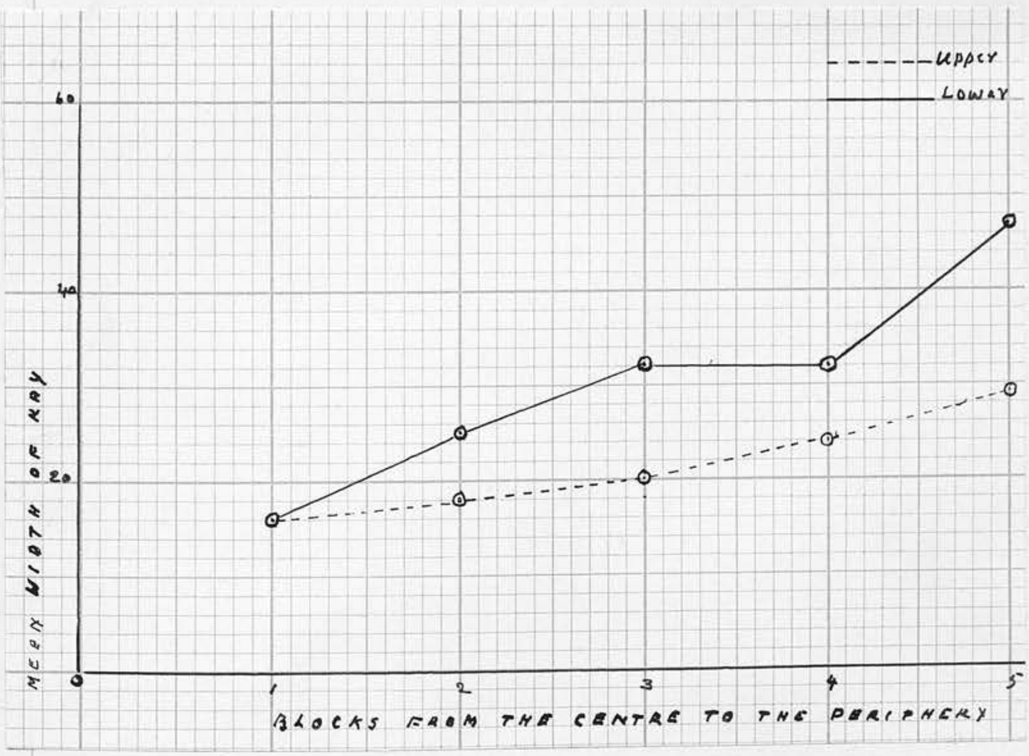


TABLE 28

Erythrina stricta

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	88	130	222	I	56	71	111
II	77	110	133	II	78	133	200
III	144	186	222	III	78	200	255
IV	122	153	166	IV	133	215	266
V	122	200	278				
VI	222	273	344				

FIG.28

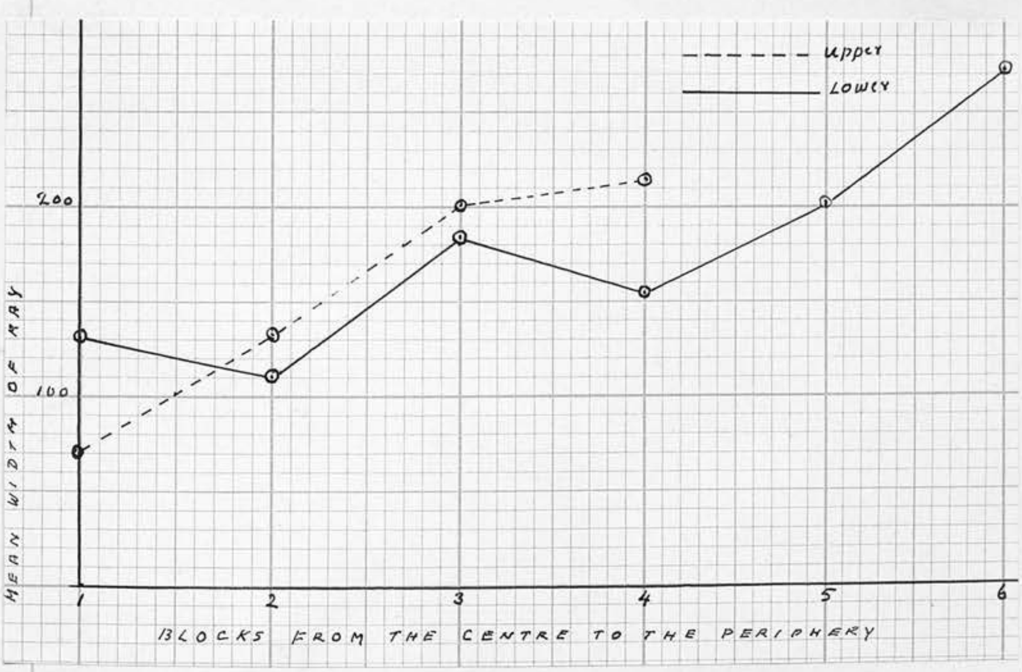


TABLE 29

Tabernaemontana dichotoma

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	33	44	56	I	33	40	44
II	33	42	44	II	33	44	56
III	44	55	67	III	44	53	56
IV	44	54	56	IV	44	53	56
V	56	73	100				

FIG.29

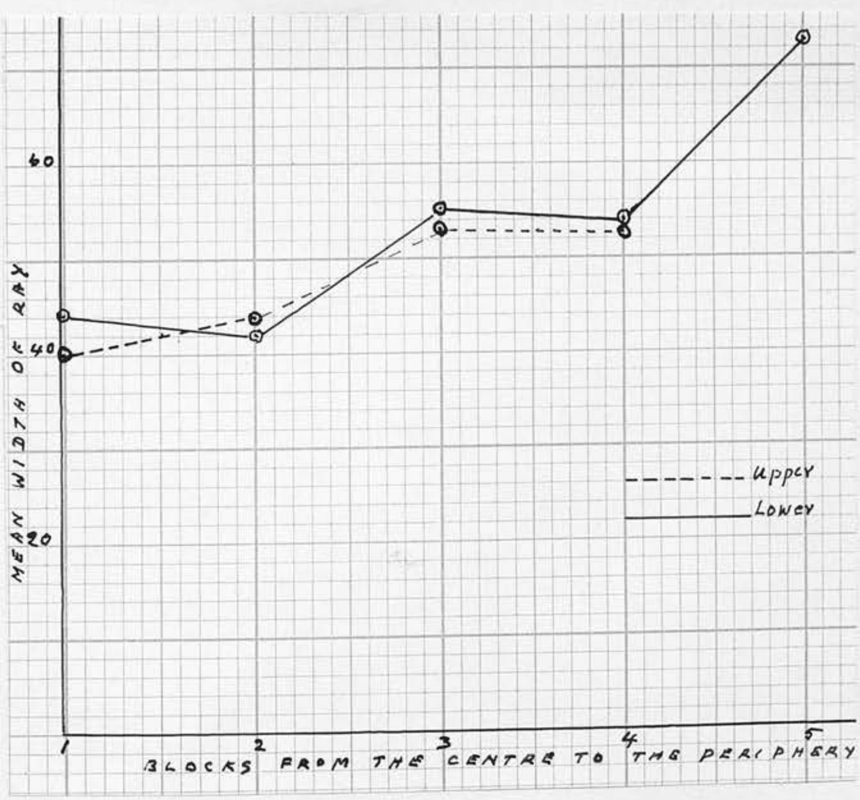
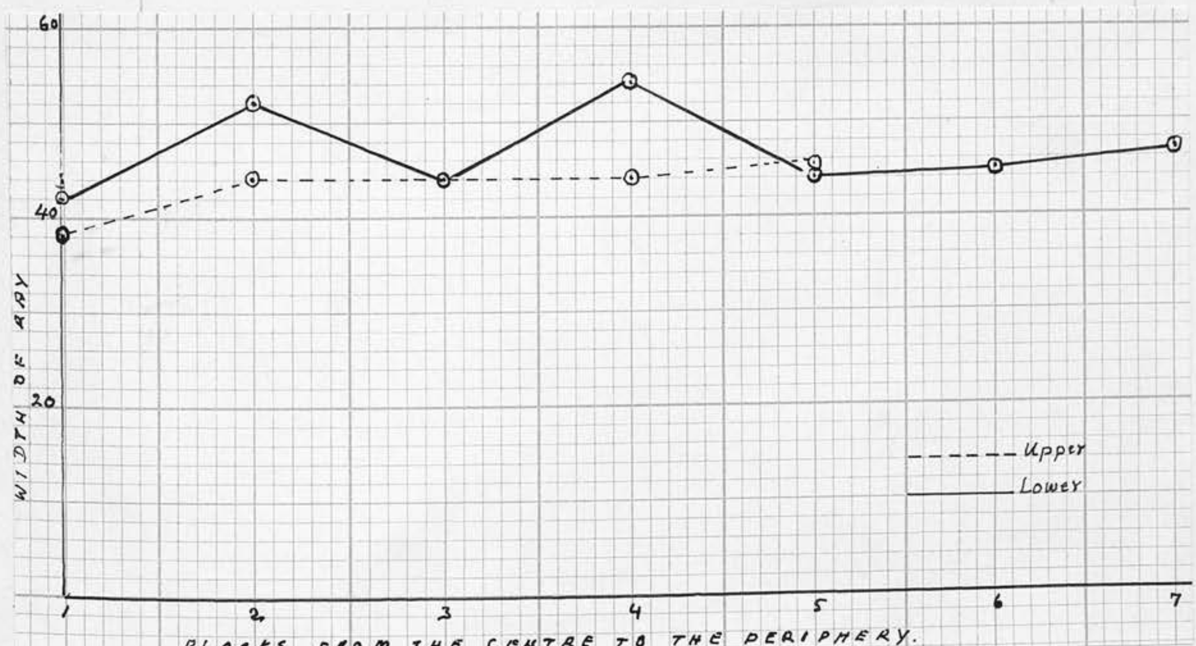


TABLE 30.

Anacardium occidentale

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	22	42	78	I	33	38	44
II	44	52	78	II	33	44	56
III	33	44	67	III	33	44	56
IV	44	54	67	IV	33	44	56
V	33	44	56	V	33	45	56
VI	33	45	56				
VII	33	47	67				

FIG.30



From the tables it is seen that the mean width of the ray increases towards the outside in all the trees in the lower and upper levels. In some cases the increase in width is noted as gradual from the inner block to the outer block and in some others it is not gradual. The rays in the outer blocks show a great increase over those of the inner block.
In _P. rheedii_ the increase is by 10.4% at the base and 68.2% at the top; in _M. peltata_ it is by 193.75% at the base and 81.2% at the top; in _E. stricta_ 110% at the base and 202.5% at the top; in _T. dichotoma_ 65.9% at the base and 32.5% at the top; and in _A. occidentale_ it increases by 11.9% at the base and 5.3% at the top.

III A detailed examination of the structure of the rays helps to explain the reasons for this increase in mean width of the ray.

In _P. rheedii_ the structure of the rays show variations. It is observed that most of the rays in the inner block are 2-seriate but a few uniseriate rays occur, whereas in the outermost block they are 3-seriate, few 2-seriate and very few uniseriate. The size of the individual cells of the ray does not show noticeable difference between the inner and outer wood. The characteristic type (Type II A Kribs) of the ray remains constant in all the blocks from the centre outward in different levels.

In _M. peltata_ both uniseriate and biseriate rays occur in the innermost block. In the outermost block they are mostly 3-seriate, few 2-seriate and rarely uniseriate; 4-seriate or 5-seriate rays also occur in the outer blocks. The individual cells of the ray in this case enlarges considerably towards the outside from the centre. In the inner block the maximum width of the ray cell is 11μ whereas in the outermost block the ray cells attain a maximum width of 28μ. The ray type (Heterogenous type I Kribs) remains constant in all the blocks.

In E. stricta the rays in the innermost block are narrow often 4-8 cells wide. In the outer block the rays are broader 4-15 cells wide. Uniseriate rays occur in all the blocks. The ray cells have a maximum width of 44μ in the inner wood, though such cells occur very seldom. In the outer blocks the ray cells attain a size of 55μ and the number of larger cells are greater in each ray. The ray type (Heterogenous Type II A Kribs) does not undergo any change.

In T. dichotoma the innermost block consists of mostly multiseriate rays of 3-4 cells wide. Triseriate rays are more frequent. In the outermost block the rays are mostly 4-seriate or 5-seriate. Uniseriate rays occur in all the blocks. The ray cells in the inner block attain only a maximum of 22μ in width whereas in the outer they reach 44μ. Such larger cells are numerous in the rays towards the periphery.

The ray type (Heterogenous type II A Kribs) remains unchanged in all.

In A. occidentale most of the rays are uniseriate and few biseriate in the inner block and in the outer they are mostly biseriate. Here there is no appreciable difference between the size of individual cells of the rays belonging to the inner and outer blocks at the same level.

From the above observations it is clear that in all cases the increase in the mean ray width towards the periphery is mainly due to the increase in the number of cells that constitute the width of the ray. Besides it is also noted that the rays do not exceed certain limit regarding their width which is probably a characteristic maximum width. The occurrence of such rays of maximum size in the outer block is not constant. The transitional sizes from the smallest to the largest are found in the outer blocks too. The percentage of smallest rays are always found to be less in the outer regions than from the inner. Hence an increase in mean width is noted in the outer regions. It is also clear that this increase in the mean width of the ray is subject to the frequency of wider rays in a particular region. Therefore there is always a change in the mean width of the rays from place to place. The gradual increase in the width of the ray is also due to the enlargement of few individual cells that constitute the ray as noted in the various materials. The plates 16-25 show the size of the rays in the inner and outer regions at the same level.

The ray type, characteristic of the species remains constant in all the blocks.

It is also observed that as the rays become broader they become shorter in all the trees studied excepting in P. rheedii and upper portions of M. peltata.

The foregoing observations explain the nature and the changes in the size of the rays from the centre to the periphery in certain tree trunks.

Discussion

Many wood anatomists consider the nature of the rays as a reliable character for the identification of wood. Barghoorn (2) disagrees with this. The observations made above support the conception that the ray structure is a diagnostic character. It is made clear that though the height and width of the ray undergo changes as the tree grows, the structure of the ray does not undergo changes to the extent of altering the specific type. De Bruyne (4) has noted an increase in width of the ray in the tree trunk from the centre to the periphery along the same radii. He maintains that the rays of two species of Pterospermum are found to change in size and structure at different ages of the tree. The trees studied above belong to an area where the climatic and ecological conditions are favourable for a continuous growth throughout the year. In these trees the size of the ray varies and the structure remains constant.

Summary.

The height of the ray is different in different places in the tree. A slight decrease is noted in some trees in the outer wood.

The mean width of ray undergoes a gradual increase towards the periphery from the centre along the same radius. This increase is largely due to the increase in the number of series of cells constituting the width of the ray and slightly due to the increase in the size of certain cells of the rays in the outer region. The width of large rays in the outer region does not exceed certain probable maximum limits for the species. The percentage of larger rays is greater in the newly formed wood. Hence the mean width increases to the outside.

The type character of the ray remains constant in lower and upper portions from the centre to the periphery. Hence it forms a reliable feature for identification of the wood.

WOOD FIBRES. - Variation in their length.

Observation.

The length of the wood fibres, was measured from the macerations of various blocks from the centre to the periphery. It is recorded below in Tables (all measurements in μ) and graphically represented in Figs. 31 - 35.

TABLE 31.

Pajanelia rheedii

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	611	805	1278	I	722	1015	1100
II	544	913	1222	II	333	991	1555
III	933	1097	1433	III	611	1029	1422
IV	833	1122	1378				
V	689	1041	1311				

FIG. 31.

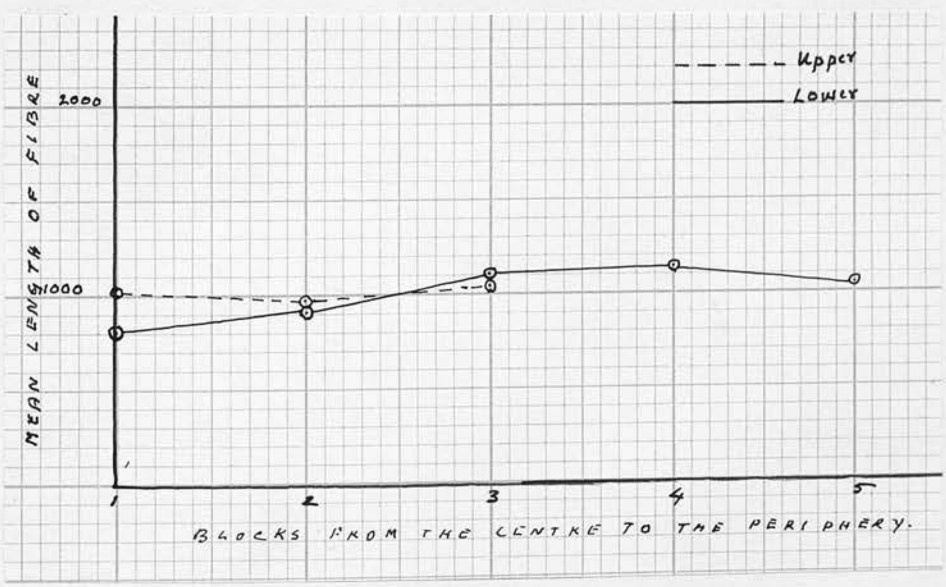


TABLE 32.

Macaranga peltata.

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	1333	1638	1866	I	1077	1284	1555
II	1111	1032	1778	II	1133	1543	2056
III	1344	1644	2111	III	1178	1480	1722
IV	1344	1586	1867	IV	1100	1425	1889
V	1111	1507	1878	V	955	1407	1666

FIG. 32.

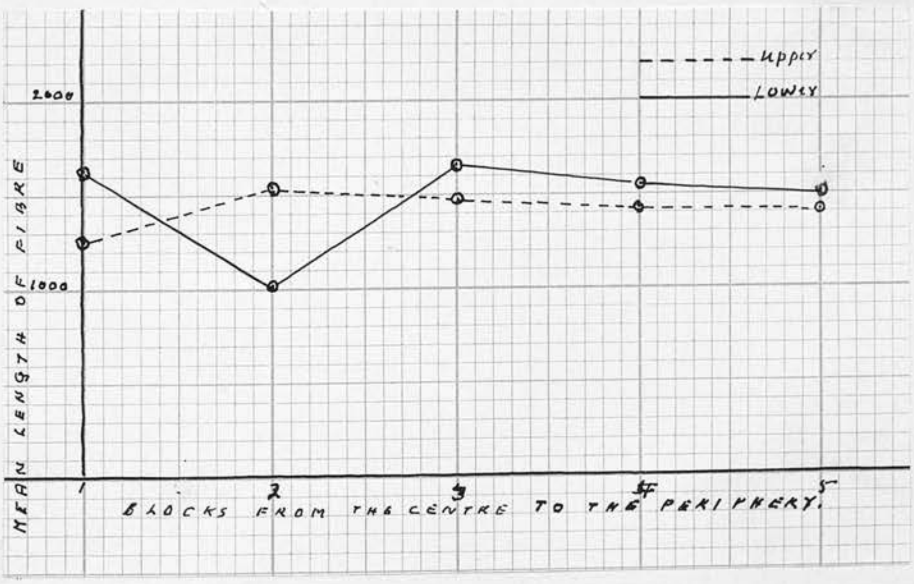


TABLE 33.

Erythrina stricta

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	955	1349	1733	I	1167	1476	1722
II	1222	1516	2055	II	1377	1817	3110
III	1067	1619	2055	III	1388	1766	2111
IV	1111	1478	1733	IV	1610	2013	2222
V	1277	1739	2277				
VI	1499	1847	2277				

FIG.33

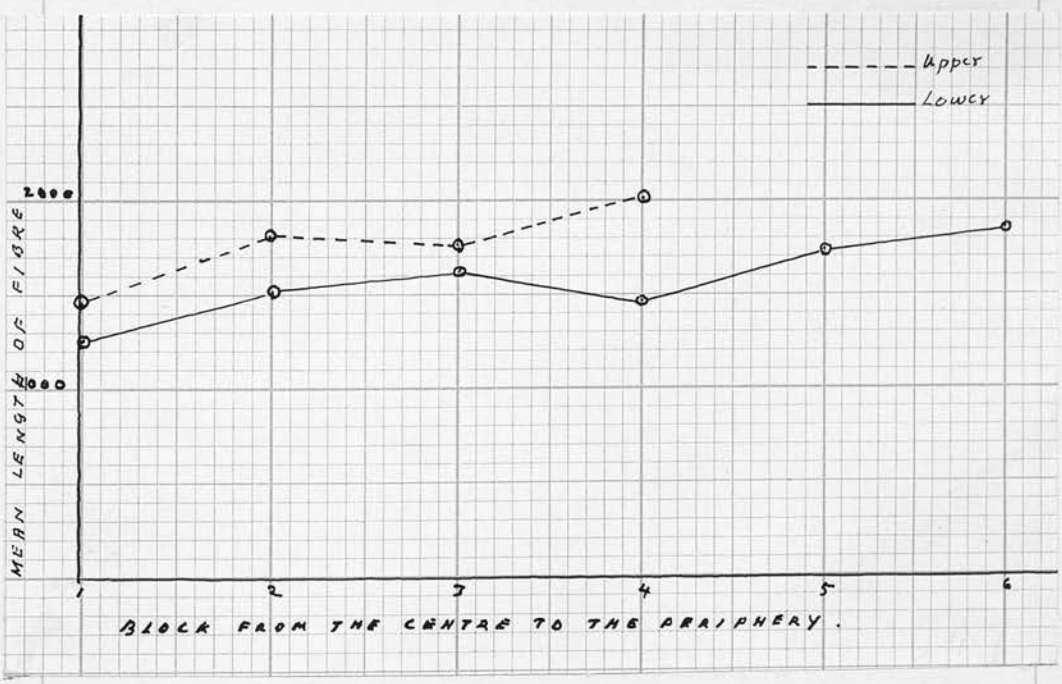


TABLE 34.

Tabernaemontana dichotoma

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	1000	1480	2267	I	1444	1722	1944
II	1333	1668	2178	II	1011	1834	2233
III	1399	1965	2233	III	1511	1850	2055
IV	1278	1973	2278	IV	1478	1703	2000
V	667	1894	2389				

FIG. 34

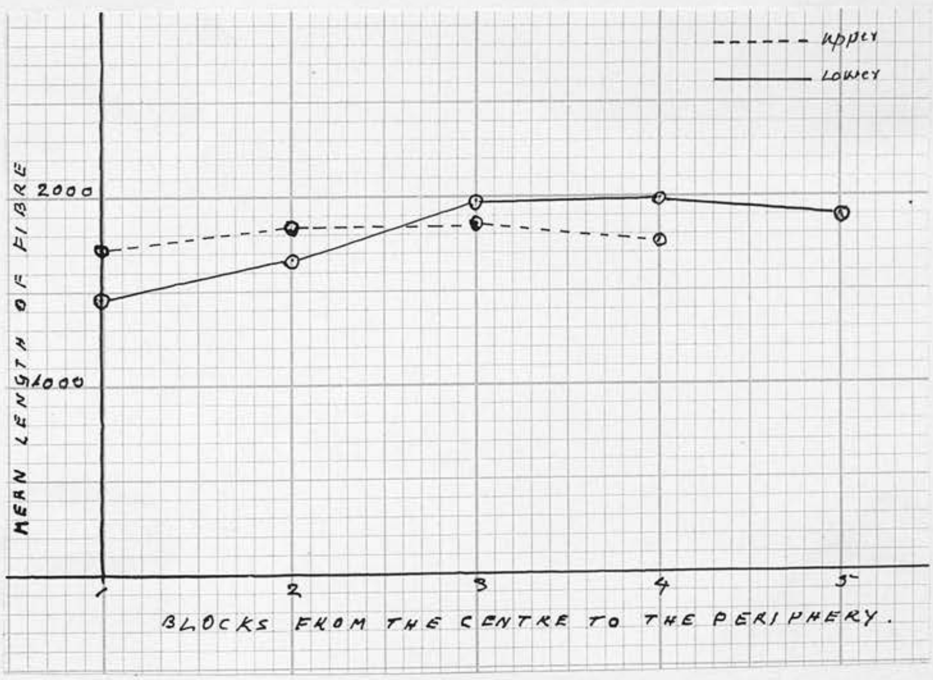
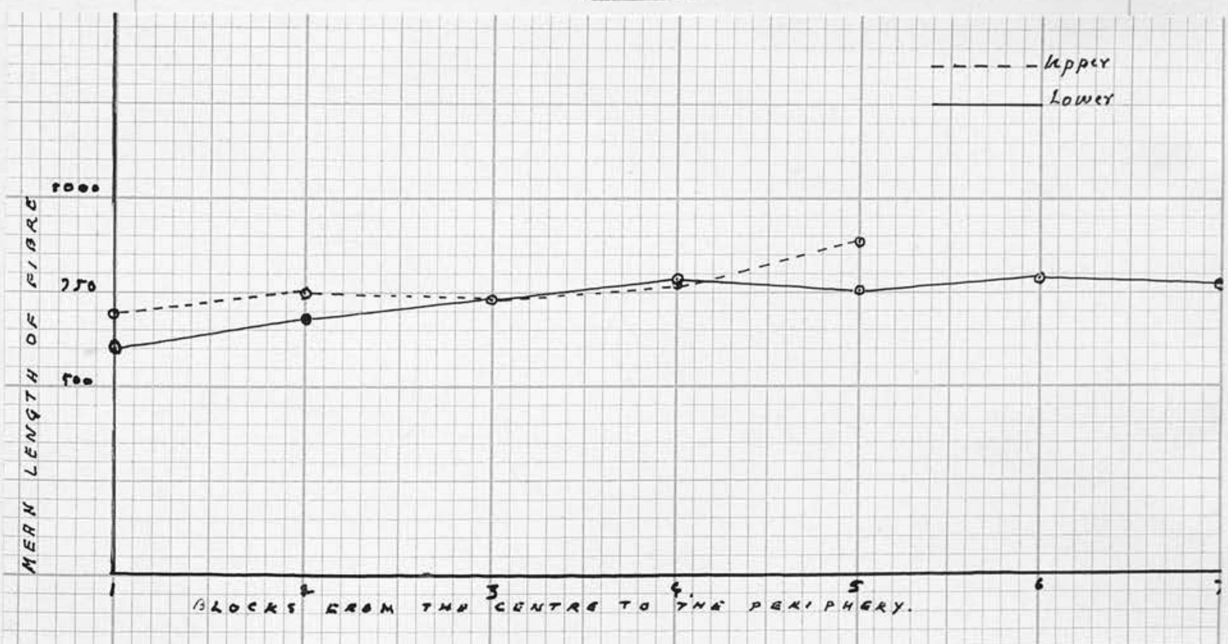


TABLE 35.

Anacardium occidentale

Lower				Upper			
Block	Min.	Mean	Max.	Block	Min.	Mean	Max.
I	411	606	689	I	556	690	833
II	611	685	733	II	578	751	944
III	611	731	833	III	333	729	889
IV	611	788	1000	IV	333	779	889
V	667	753	889	V	722	839	1055
VI	578	785	955				
VII	667	776	1022				

FIG.35



The Tables make clear that the length of the wood fibres varies from place to place at different levels. At the same time they show that in all the trees there is an increase in length of the fibres in the outermost block from the innermost one both in the lower and upper regions except in M. peltata and T. dichotoma, which show a reduction. The reduction in these two is negligible. There is no gradual increase in the fibre length from the centre outward. In some cases the middle blocks have longer fibres than those of the outermost one.

From the observations it is clear that there is no constancy regarding the length of the fibre occurring in the different parts of the secondary wood. The length of the fibre does not become fixed to form a feature characteristic of a species.

Summary.

The wood fibres are longer in the outer regions than those of the inner regions of the tree trunk. They always show great variations from place to place in both outer and inner regions. The length of the fibre does not become fixed to form a definite feature characteristic of the species.

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2. BARGHOORN, E.S. The ontogenetic development and phylogenetic specialization of rays in the xylem of Dicotyledons. 11. Modification of the multiseriate and uniseriate rays. Am. J. Bot. 28: 273 - 281. 1941.

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PAJANELIA RHEEDII

PLATE	1.	T.S.	x 50.	Inner Block
"	2.	" "	"	Middle "
"	3.	" "	"	Outer "

MACARANGA PELTATA

PLATE	4.	T.S.	x 50.	Inner Block
"	5.	" "	"	Middle "
"	6.	" "	"	Outer "

ERYTHRINA STRICTA

PLATE	7.	T.S.	x 50.	Inner Block
"	8.	" "	"	Middle "
"	9.	" "	"	Outer "

TABERNAEMONTANA DICHOTOMA

PLATE	10.	T.S.	x 50.	Inner Block
"	11.	" "	"	Middle "
"	12.	" "	"	Outer "

ANACARDIUM OCCIDENTALE.

PLATE	13.	T.S.	x 50.	Inner Block
"	14.	" "	"	Middle "
"	15.	" "	"	Outer "

PAJANELIA RHEEDII

PLATE 16.	T.L.S. x 45.	Inner Block
" 17.	" " " "	Outer "

MACARANGA PELTATA

PLATE 18.	T.L.S. x 45.	Inner Block
" 19.	" " " "	Outer "

ERYTHRINA STRICTA

PLATE 20.	T.L.S. x 45.	Inner Block
" 21.	" " " "	Outer "

TABERNAEMONTANA DICHOTOMA

PLATE 22.	T.L.S. x 45.	Inner Block
" 23.	" " " "	Outer "

ANACARDIUM OCCIDENTALE

PLATE 24.	T.L.S. x 45.	Inner Block
" 25.	" " " "	Outer "

PLATE I

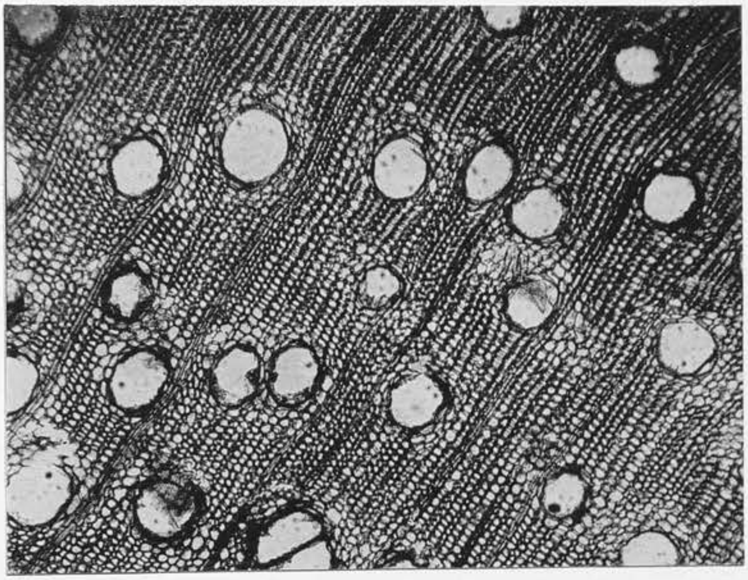


PLATE 2

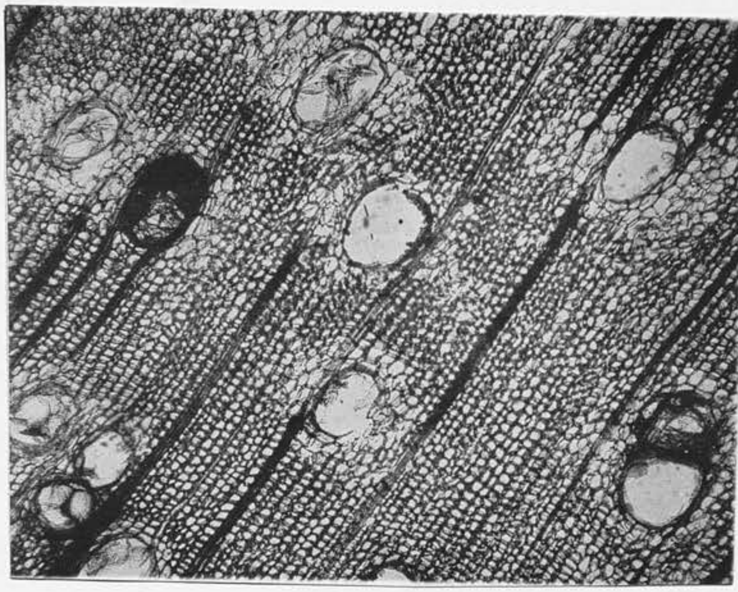
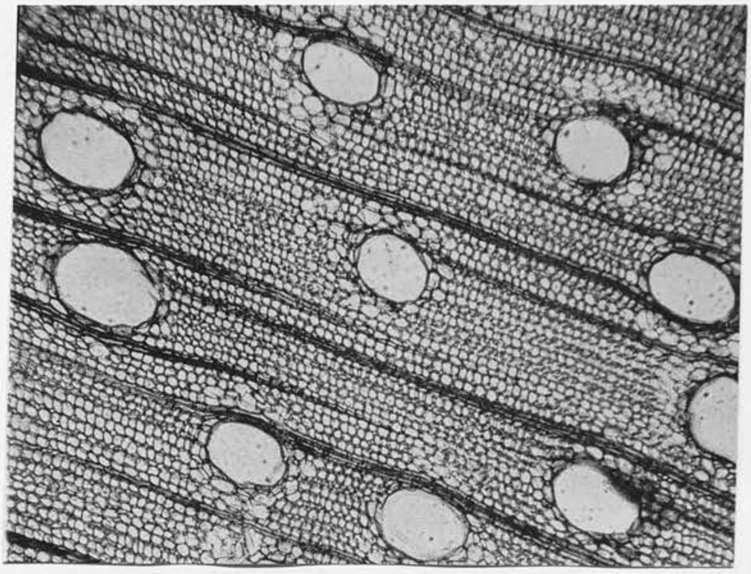


PLATE 3



Pajanelia rheedii

PLATE 4

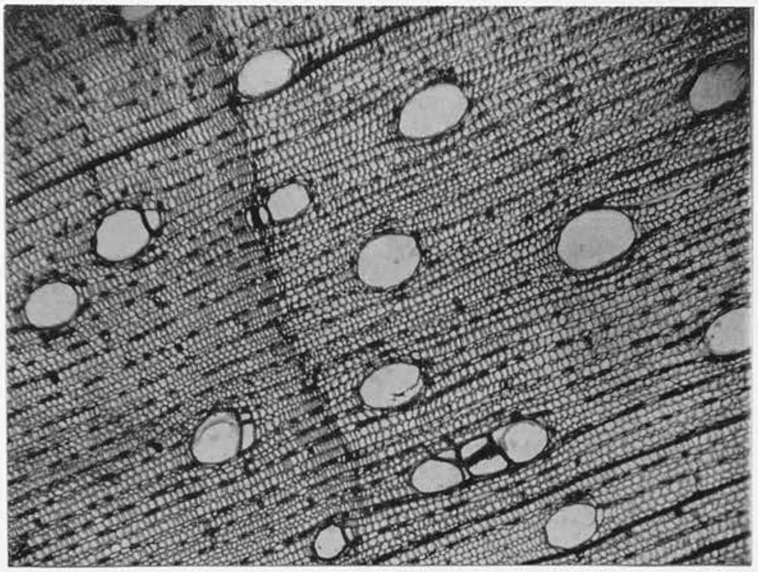


PLATE 5

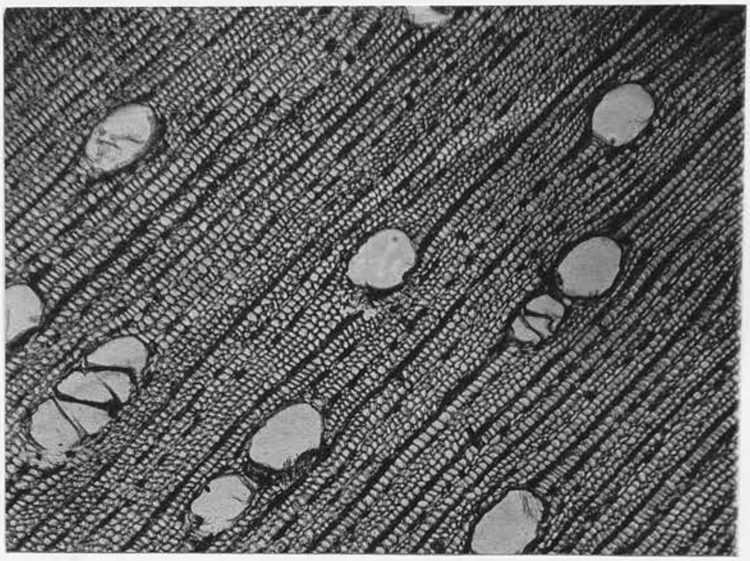
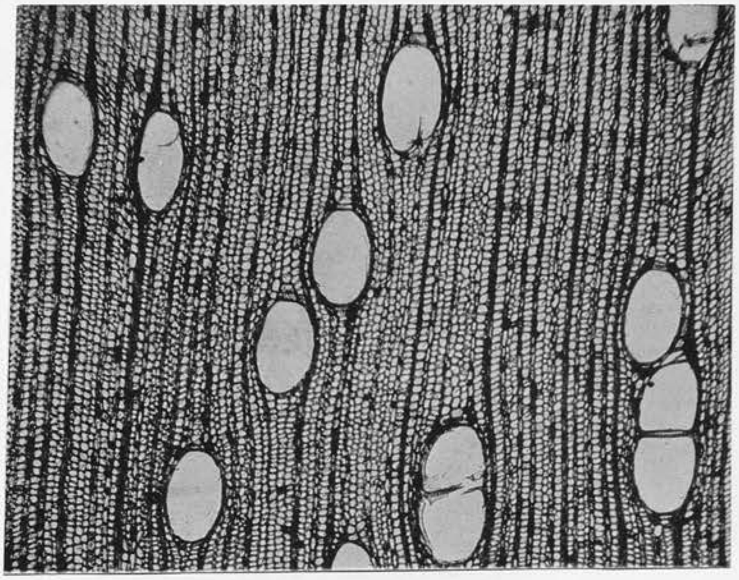


PLATE 6



Macaranga peltata.

PLATE 7

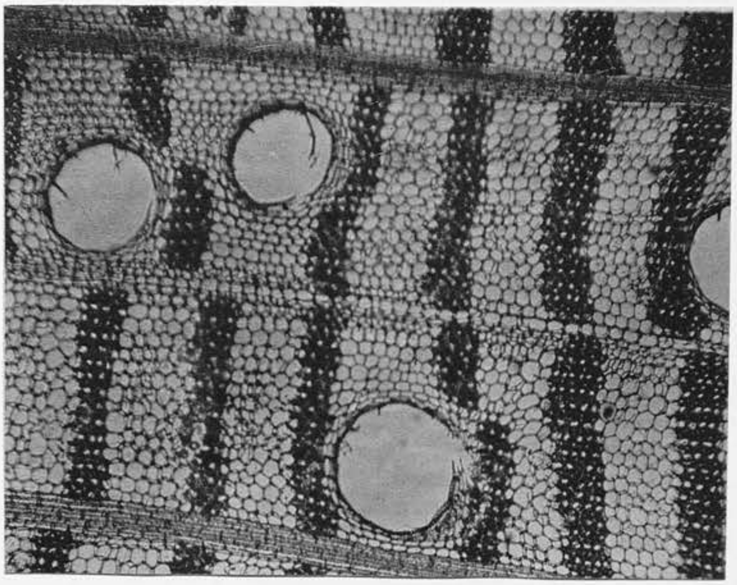


PLATE 8

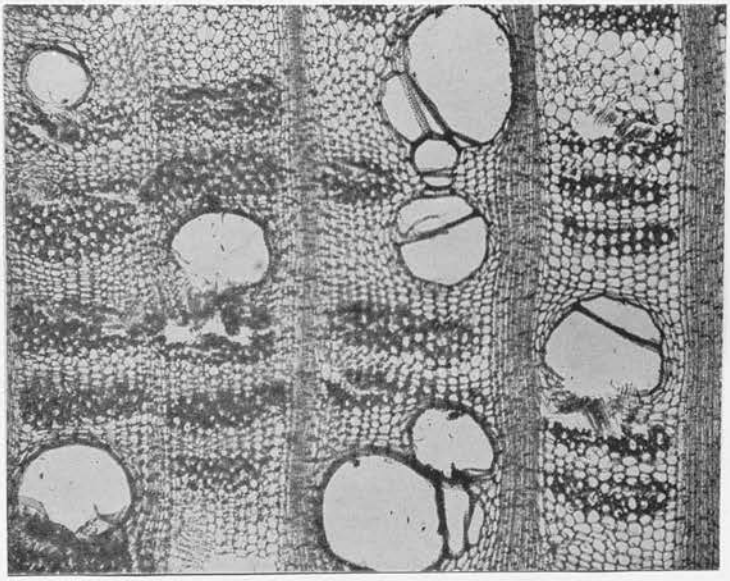
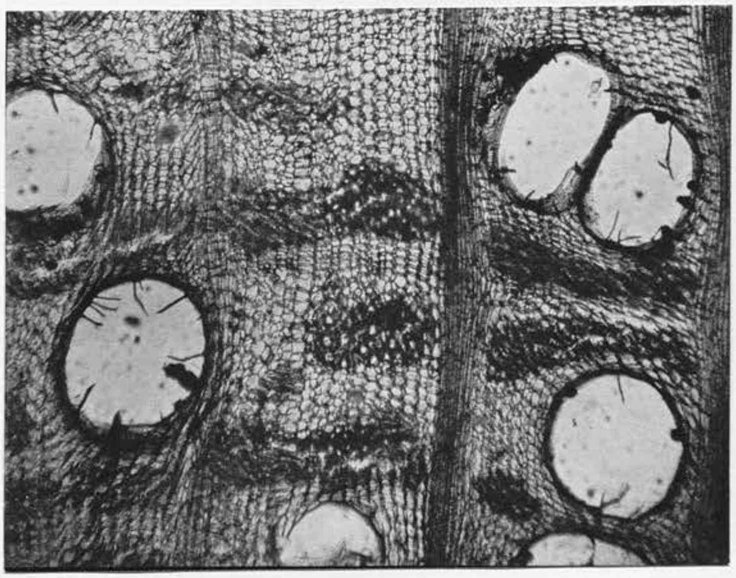


PLATE 9



Erythrina stricta.

PLATE 10

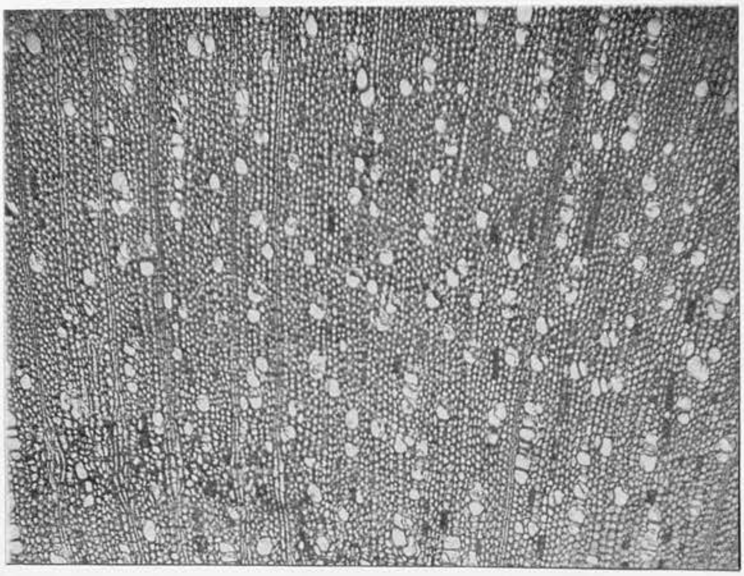


PLATE 11

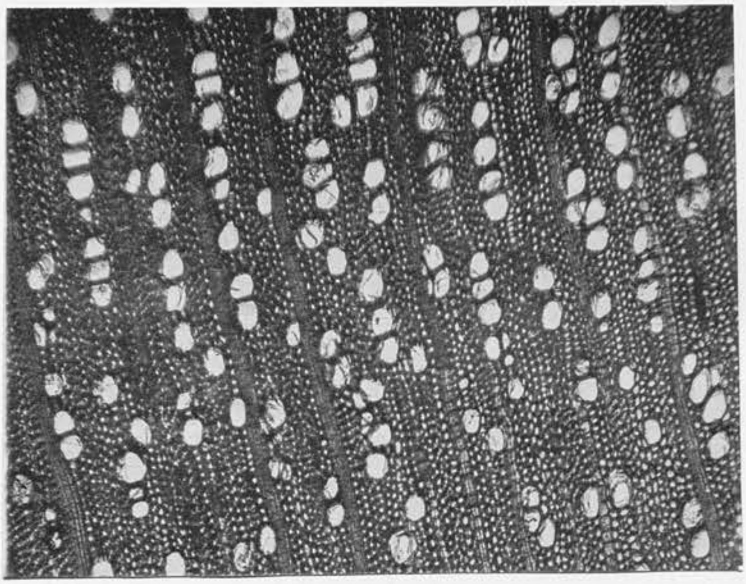
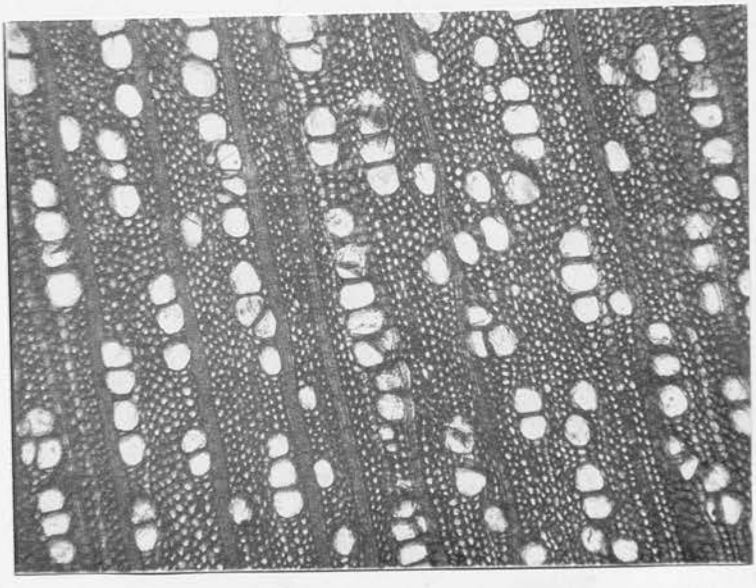


PLATE 12



Tabernaemontana dichotoma.

PLATE I3

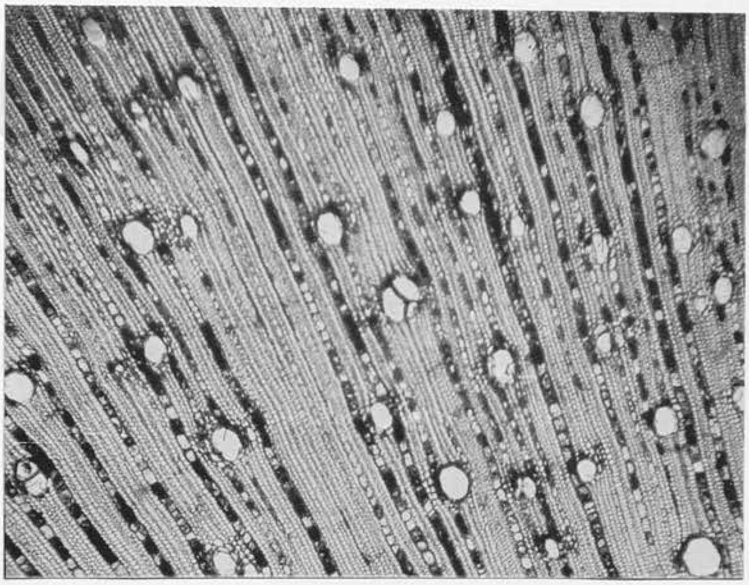


PLATE I4

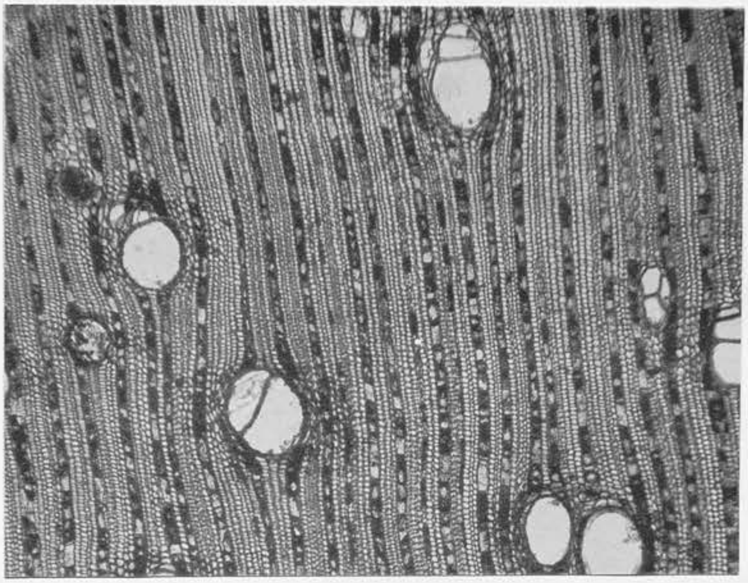
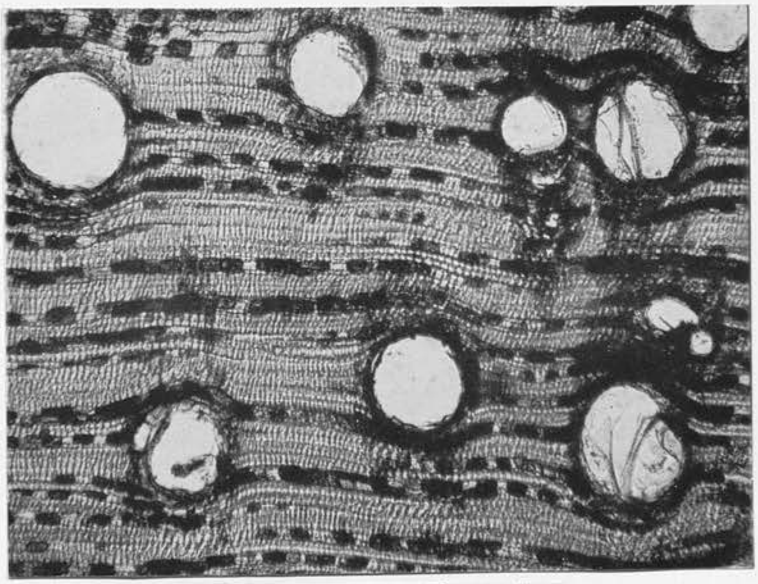


PLATE I5



Anacardium occidentale.

PLATE 16

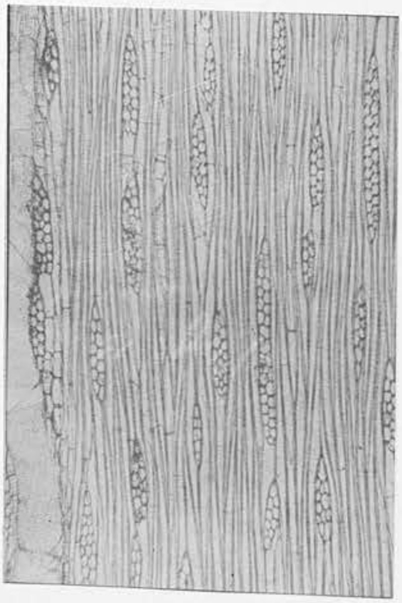
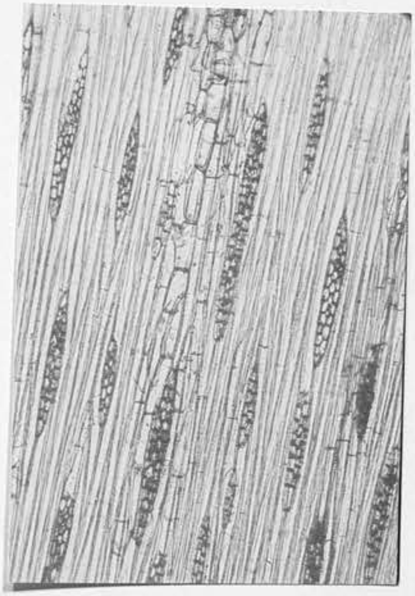


PLATE 17.



Pajanelia rheedii.

PLATE I8.

PLATE I9.

Macaranga peltata.

PLATE 20.

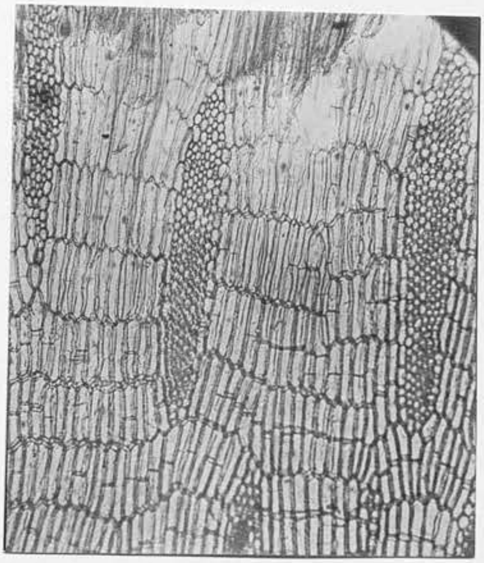
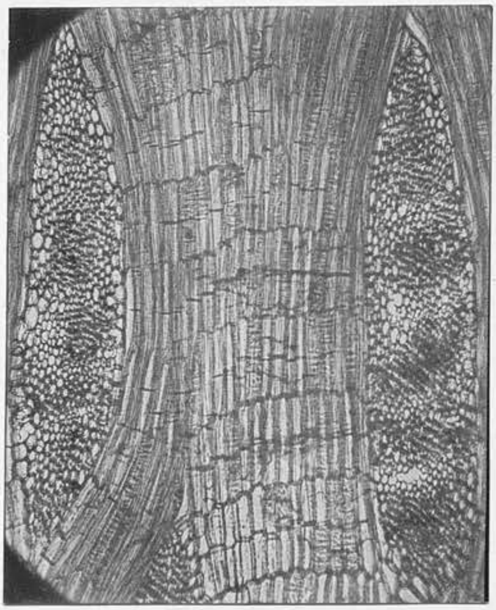


PLATE 2I.



Erythrina stricta.

PLATE 22.

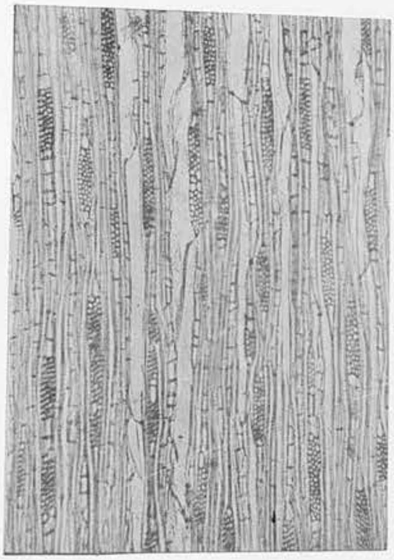
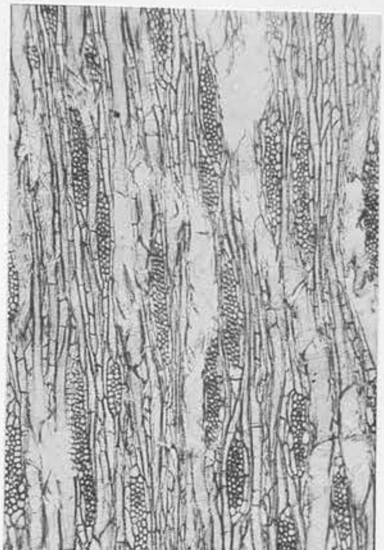


PLATE 23.



Tabernaemontana dichotoma

PLATE 24.

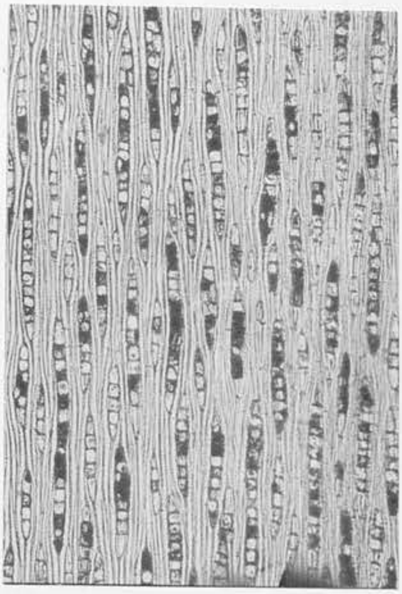
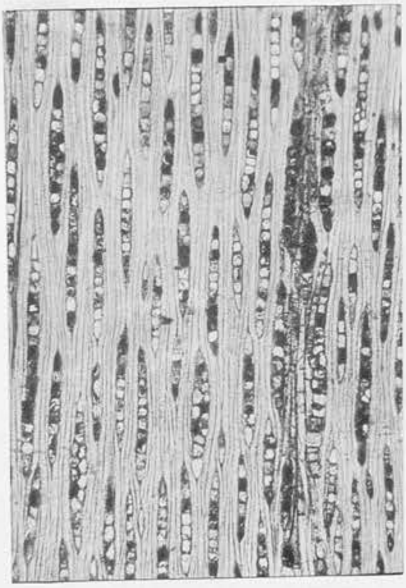


PLATE 25.



Anacardium occidentale.